NASA

National Aeronautics and Space Administration

Budget Estimates

FISCAL YEAR 1990

Volume I

Agency Summary

Research and Development

Space Flight, Control and Data Communications

PHYSICS AND
ASTRONOMY

CONTENTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1990 ESTIMATES

VOLUME 1

TABLE OF CONTENTS

AGENCY SUMMARY

RESEARCH AND DEVELOPMENT

AGENCY SUMMARY

Space Transportation

The Space Shuttle has safely returned to flight and the primary program objective of the current budget is completion of this recovery effort and conducting the planned flights in a safe and reliable manner, and to provide for the necessary capabilities to fly the payloads scheduled for launch. The budget provides for five flights in FY 1989 and nine flights in FY 1990, ultimately leading to a capability of fourteen flights per year. Design and development activities will continue in FY 1990 to complete those activities associated with the redesigned solid rocket motor and to continue efforts to expand the operating margins in the main engines and development of the Advanced Solid Rocket Motor (ASRM). The ASRM is intended to improve the safety, reliability and performance of the Shuttle fleet. Development of improvements to the Shuttle for extending the stay time in orbit will be continued with NASA seeking private sector investment for elements of this program.

In other aspects of Space Transportation, the FY 1990 budget includes funding for procurement of Upper Stages, the preparation of the Spacelab to resume flights in 1990, continued development of the Orbital Maneuvering Vehicle, the Tethered Satellite System and the Advanced Launch System. Development of a docking module for use between the Shuttle and Space Station or other spacecraft requiring this capability will be initiated, with private sector investment being pursued for the docking module development. Funding for expendable launch vehicle services for selected Space Science and Applications missions implementing NASA's mixed fleet plan is included, as well as for other activities necessary to provide the basis for a robust space transportation system.

Space Station

The Space Station Freedom program is the centerpiece of the Nation's space program of the 1990s. The Space Station will provide our first opportunity to gain direct experience in long term human operations in space, and knowledge essential to future space exploration. It will enhance the U.S. space science programs, further the commercial utilization of space, and stimulate the development and application of advanced technologies of national importance. It is also an avenue of cooperation with our allies, demonstrating the peaceful use of space for the benefit of all. The Space Station Freedom has seen significant progress during the past year. The development plan and configuration are firm and the development contractors are making substantial progress. Negotiations with the international partners for the development phase of the program were completed in the fall of 1988. Agreements have been signed with the Canadian government and member countries of ESA, with a formal signing of the memorandum of understanding with the Japanese government expected in the spring of 1989.

In addition to supporting the request for nearly $2.1 billion of new obligational authority in FY 1990, the Administration is proposing legislation for a three year Congressional commitment for advanced authorization and appropriations of $8.5 billion including the FY 1990 amount. The Administration is also proposing legislation to establish a total development program cost ceiling of $13.0 billion (in 1984

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1990 BUDGET ESTIMATES

GENERAL STATEMENT

The National Aeronautics and Space Administration conducts space and aeronautical research, development and flight activities for peaceful purposes designed to maintain United States preeminence in aeronautics and space. The National Space Policy emphasizes continuing the national commitment to a permanently manned Space Station, pursuing vigorous programs in space science and space technology, creating opportunities for United States commerce in space and the long-range goal of expanding human presence and activity beyond Earth orbit into the solar system. The priority given to the National Space Policy is clearly demonstrated by the increased funding recommended for civil space programs in this budget.

The NASA FY 1990 budget request of **$13.3** billion supports the National Space Policy by providing the resources necessary to support a vigorous national program ensuring leadership in areas critical to space as well as continued preeminence in aeronautics. This budget concentrates on:

- Providing for safe and effective Space Transportation Operations and assured access to space using both the Space Shuttle and Expendable Launch Vehicles;

- Moving forward in the establishment of a permanently occupied Space Station in Earth orbit;

- Continuing an effective Space Science and Applications program to expand our knowledge of the Earth, its environment, the solar system and the universe and human habitation of space;

- Strengthening the basic capabilities of NASA and developing the technology base €or future orbital operations and exploration of space;

- Providing the facilities, technology and expertise necessary for superiority in civil and military aviation;

- Providing opportunities for commercialization of space through private sector participation including investment in major civil space program activities, and for international cooperation in space.

The program elements outlined in this budget will provide a strengthened base for assuring and continuing the United States' role as leader in space and aeronautical research and development. Specific major areas of emphasis are:

dollars, adjusted for inflation and commercialization). In addition, consistent with the Administration's policy, NASA will be actively pursuing approaches to encourage private sector participation, including investment, in the Flight Telerobotic Servicer capability, the Space Station docking system and future requirements for the Space Station, including those under study, e.g., Solar Dynamic Power and equipment to utilize the Space Station. Funding is included to initiate the development of a radar to track and monitor small size orbital debris.

Space Science and Applications

The FY 1990 budget provides for a carefully coordinated and logically phased set of research and development activities to:

- Advance our scientific knowledge of Earth and of the forces and systems that shape our planet;

- Explore the solar system using automated spacecraft in conjunction with ground-based observations and research;

- Expand our comprehension of the universe beyond the solar system using the full range of capabilities from Explorer spacecraft to the orbiting Great Observatories;

- Increase our knowledge in the Life Sciences on key issues ranging from human performance and habitation in space to the basic life processes and the potential of life elsewhere in the universe; and

- Understand and develop the potential benefits of the microgravity environment in materials sciences and other applications.

The Space Science and Applications program is ready to take full advantage of the resumption of access to space through the Shuttle and Expendable Launch Vehicles services. Current planning supports launch of Magellan and Galileo in 1989, launch of the Hubble Space Telescope in late 1989, and launch of Ulysses and the Gamma Ray Observatory in 1990. The Cosmic Background Explorer and Roentgen Satellite are scheduled to be launched on Delta expendable launch vehicles in 1989 and 1990, respectively. Development continues on the Gamma Ray Observatory, the Upper Atmosphere Research Satellite, the Mars Observer, the Ocean Topography Experiment, the Global Geospace Science Mission, the Collaborative Solar Terrestrial Research program and mirror and science instrument development in preparation for the start of the Advanced X-ray Astrophysics Facility spacecraft in 1992. Development and Integration activity continues in preparation for future Spacelab missions and for secondary payloads to conduct microgravity and life sciences experiments. Funds are also included to initiate design and development of the Comet Rendezvous/Asteroid Fly-by/Cassini missions. These missions will send one spacecraft to study at close range a comet and its total environs and a second spacecraft to study the planet Saturn, its atmosphere, rings and its moon, Titan. This project will include participation by the Federal Republic of Germany and the European Space Agency. Funding is also included to continue data processing and investigations from the Voyager 1 and 2 spacecrafts as they leave the solar system. These spacecraft will gather data on the interstellar fields and particles unaffected by the solar plasma.

Commercial Activities

The FY 1990 budget supports development of the private sector innovative excellence and confirms NASA's commitment to encouraging a healthy and expansive commercial space industry. Funding is included for the integration of a commercially developed space facility into the Shuttle and, in future years, lease of space for government payloads. NASA plans to procure launch services from the private sector for a number of important scientific satellite missions. Commercially-developed upper stages are being used where appropriate for planned missions. Commercial microgravity experiments to be conducted as secondary payloads are manifested on planned Shuttle missions. NASA will actively pursue approaches to encourage the private sector to invest in elements of several NASA programs, including the Flight Telerobotic System, the Extended Duration Orbiter, and the Space Station Docking System. There are several initiatives underway to involve the private sector in developing the infrastructure necessary for research and manufacturing in space, and NASA strongly supports these initiatives. An agreement was concluded in FY 1988 to provide launch services on a deferred payment basis for the commercially developed "Spacehab" microgravity facility which will fly on the Shuttle, and an agreement has been signed with the University Corporation for Atmospheric Research for use of the Shuttle external tanks.

Space Research and Technology

This program develops the technology base on which our current and future capabilities in space depend. The Civil Space Technology Initiative started in FY 1988, and the Pathfinder program started in FY 1989 will develop technology requirements for future missions and significantly enhance current capabilities to access and operate in space at greatly reduced overall mission costs. The in-space flight experiments technology program is also included as a new initiative. This program provides for the development and/or demonstration of critical technologies which require the actual space environment and will provide precursor information for the development of advanced technology experiments to be flown on the Space Station.

Aeronautics Research and Technology

The goal of the Aeronautics program is to provide a technology base for the continued U.S. preeminence in the field of aeronautics. This is accomplished by maintaining a broad based research and technology program utilizing advanced facilities, laboratories, computers and technical staff, with extensive involvement of the U.S. university and industrial sectors.

The FY 1990 Research and Technology program is committed to developing the technology to improve our nation's competitiveness and product superiority in the international marketplace, enhancing the safety of aviation, and increasing U.S. leadership in aviation for national security. A funding augmentation is included for high-speed research which will focus on resolution of the critical environmental issues concerning ozone depletion, airport noise and sonic booms to make informed decisions on high-speed aircraft development in the future.

Transatmospheric Research and Technology

The NASA efforts in this area are aimed at accelerating the development of critical technologies intended to enable a potential new class of vehicles in the future capable of flight to orbit and/or hypersonic cruise. Work will continue in the development of technology for hypersonic and transatmospheric vehicles for the National Aerospace Plane program with emphasis on lightweight thermal structures and subsonic and supersonic propulsion. Potential future applications include vehicles to transport people to orbit, hypersonic transport between points on Earth and military defense.

Space and Ground Network. Communications and Data Systems

The FY 1990 budget provides vital tracking, telemetry, command, data acquisition, communications and data processing support to meet the requirements of all NASA flight projects. Work will continue on the replacement Tracking and Data Relay Satellite (TDRS) spacecraft and on the Second TDRSS Ground Terminal both of which are vitally needed to insure continuity of tracking support

University Space Science and Technology Academic Program

This new budget line item provides for continuation of agency-wide university and minority university programs previously budgeted in other NASA programs. FY 1990 funding will support graduate and undergraduate student fellowships, faculty fellowships, the historically black colleges and university research program, other minority universities, and the Space Grant College and Fellowship program.

Work Force Capability

The NASA institutional capability is the underpinning for the successful accomplishment of the nation's aeronautics and space programs. The FY 1990 budget provides funding for an increase in civil service people who are urgently required to meet the staffing levels associated with Space Station and to strengthen NASA's science and engineering core workforce. Hands on work in-house gives NASA the knowledge to manage the 85 percent of NASA's work that is contracted to private industry, and the ability to respond quickly to management or technical problems as they occur.

Construction of Facilities

The FY 1990 budget provides funding for construction of new facilities as well as the maintenance and repair of the NASA physical plant. The principal projects planned for FY 1990 include facilities needed for space flight, Space Station, space technology, and space science and applications activities, continuation of the multiyear effort to restore and modernize NASA's aeronautical research and development facilities and support of minor projects and future planning activities. Private sector financing will be sought for the Neutral Buoyancy Laboratory at the Johnson Space Center, the Space Station processing facility at the Kennedy Space Center, the Advanced Solid Rocket production and test facility, and the Observational Instruments Laboratory at the Jet Propulsion Laboratory.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FY 1990 BUDGET SUMMARY
(Millions of Dollars)

	Budget Plan 1988	1989	1990
RESEARCH AND DEVELOPMENT	3.254.9	4.266.6	5,751.6
Space station	392.3	900.0	2,050.2
Space transportation capability development	593.4	681.0	639.0
Space science and applications	1,581.8	1,830.2	1,995.3
Technology utilization	19.0	16.5	22.7
Commercial use of space	29.7	28.2	38.3
Aeronautical research and technology	332.9	404.2	462.8
Transatmospheric research and technology	52.5	69.4	127.0
Space research and technology	221.3	295.9	338.1
Safety, reliability and quality assurance	14.1	22.4	23.3
University space science and technology academic program	(21.6)	(22.3)	35.0
Tracking and data advanced systems	17.9	18.8	19.9
SPACE FLIGHT. CONTROL AND DATA COMMUNICATIONS	3.805.7	4.464.2	5,139.6
Shuttle production and operational capability	1,092.7	1,128.2	1,305.3
Space transportation operations	1,833.6	2,390.7	2,732.2
Space and ground networks, communications and data systems	879.4	945.3	1,102.1
CONSTRUCTION OF FACILITIES	178.3	275.1	341.8
RESEARCH AND PROGRAM MANAGEMENT	1,762.2	1.891.6	2.032.2
INSPECTOR GENERAL	(7.1)	(8.6)	8.8
TOTAL BUDGET SUMMARY	9.001.1	10.897.5	13.274.0
OUTLAYS	9.091.6	10.678.0	12.706.8

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FISCAL YEAR 1940 ESTIMATES
SUMMARY RECONCILIATION OF APPROPRIATIONS TO BUDGET PLANS

(Millions of Dollars)

	TOTAL	Research and Development	SFC&DC	C of F	R&PM	Inspector General
FISCAL YEAR 1988						
Appropriation P. L. 100-202	8,856.5	3,274.2	3,908.3	178.3	1,495.7	(7.1)
Reappropriation P L. 100-202	100.0	100.0	---	---	---	---
Recission P. L 100-404	-25.0	-25.0	---	---	---	---
Transfer between accounts	0.0	-159.4	-102.6	---	262.0	---
Transfer between Fed Agencies	70.0	65.1	---	---	4.9	---
Laps,	-0.4	---	---	---	-0.4	---
Total Budget Plan	9,001.1	3,254.9	3,805.7	178.3	1,762.2	0.0
FISCAL YEAR 1989						
Appropriation P. L. 100-404	10,701.0	4,191.7	4,364.2	290.1	1,855.0	(8.6)
Transfer between accounts	0.0	---	---	-30.0	30.0	---
Transfer between Fed Agencies	196.5	74.9	100.0	15.0	6.6	---
Total Budget Plan	10,897.5	4,266.6	4,464.2	275.1	1,891.6	(8.6)
FISCAL YEAR 1990						
Appropriation Request/Budget Plan	13,274.0	5,751 6	5,139.6	341.8	2,032.2	8 8

NATIONAL AERONAUTICS SPACE ADMINISTRATION

FISCAL YEAR 1990 ESTIMATES

SUMMARY OF BUDGET PLANS BY INSTALLATION BY APPROPRIATION

(Thousands of Dollars)

	Total			Space Flight Control and Data Communications			Research and Development			Construction of Facilities			Research and Program Management		
	1988	1989	1990	1988	1989	1990	1988	1989	1990	1988	1989	1990	1988	1989	1990
Johnson Space Center	1,528,266	1,880,945	2,659,096	907,750	1013,000	1,119,600	327,452	549,945	1,167,440	[illegible]	24,345	48,085	[illegible]	301,755	323,171
Kennedy Space Center	1,074,553	1,196,581	1,398,422	719,700	801,400	870,000	86,016	113,401	185,254	[illegible]	18,350	63,165	[illegible]	263,430	279,263
Marshall Space Flight Center	2,262,369	2,691,334	3,053,254	1,261,200	1576,400	1,788,000	744,426	825,281	979,660	[illegible]	39,780	19,085	[illegible]	249,873	265,709
Stennis Space Center	60,717	76,052	68,042	19,100	20,000	18,400	16,179	10,070	14,054	[illegible]	22,505	9,705	[illegible]	24,207	25,883
Goddard Space Flight Center .	1,233,856	1,591,682	2,006,732	464,335	559,600	719,000	506,843	764,949	984,033	[illegible]	14,120	32,460	[illegible]	253,013	271,239
Jet Propulsion Laboratory	624,983	689,058	754,009	131,515	126,000	158,400	486,314	557,558	583,559	[illegible]	5,500	12,050	[illegible]	0	0
Ames Research Center	476,207	511,884	593,407	15,400	17,200	20,500	261,102	282,024	332,711	[illegible]	34,332	53,235	[illegible]	178,328	186,061
Langley Research Center	382,374	455,665	506,165	100	4,000	8,000	197,149	240,756	272,095	[illegible]	21,760	24,575	[illegible]	189,149	201,495
Lewis Research Center	463,056	636,962	821,972	3,700	29,900	55,300	254,752	387,232	525,817	[illegible]	25,630	33,065	[illegible]	194,200	207,790
Headquarters	878,014	1,102,939	1,358,466	282,000	315,000	380,000	374,587	535,384	706,977	[illegible]	15,000	0	[illegible]	237,555	270,689
Undistributed Construction of Facilities:															
Various Locations	8,637	33,698	19,335	0	0	0	0	0	0	8,637	33,698	19,335	0	0	0
Facility Planning and Design	16,000	20,000	26,300	0	0	0	0	0	0	16,000	20,000	26,300	0	0	0
Total Budget Plan	9,001,032	10,897,500	13,265,200	3,805,700	4,464,200	5,139,600	3,254,900	4,266,600	5,751,600	178,272	275,100	341,000	1,762,160	1,891,600	2,032,200
Inspector General	(7,100)	(8,600)	8,795	---	---	---	---	---	---	---	---	---	---	---	---
Total Agency	[illegible]	[illegible]	[illegible]												

DISTRIBUTION OF PERMAMENT CIVIL SERVICE WORKYEARS BY INSTALLATION

	1988 ACTUAL	1989 BUDGET ESTIMATE	1989 CURRENT ESTIMATE	1990 BUDGET ESTIMATE
JOHNSON SPACE CENTER.........	3,302	3,460	3,463	3,605
KENNEDY SPACE CENTER.........	2,167	2,324	2,331	2,357
MARSHALL SPACE FLIGHT CENTER.	3,351	3,461	3,481	3,607
STENNIS SPACE CENTER.........	140	159	166	174
GODDARD SPACE FLIGHT CENTER..	3,585	3,584	3,618	3,651
AMES RESEARCH CENTER.........	2,065	2,068	2,097	2,153
LANGLEY RESEARCH CENTER......	2,811	2,812	2,835	2,888
LEWIS RESEARCH CENTER........	2,640	2,646	2,664	2,743
HEADQUARTERS.................	1,320	1,416	1,403	1,431
INSPECTOR GENERAL............	119	151	136	0
SUBTOTAL, FULL-TIME PERMANENT WORKYEARS	21,500	22,081	22,194	22,609
OTHER THAN FULL-TIME PERMANENT WORKYEARS	682	726	738	743
SUBTOTAL, CEILING CONTROLLED FTE	22,182	22,807	22,932	23,352
SPACE STATION (RESTON, VA)	144	143	218	348
TOTAL, CEILING CONTROLLED FTE	22,326	22,950	23,150	23,700

NOTE: THE INSPECTOR GENERAL'S OFFICE WAS GRANTED ITS OWN APPROPRIATION, THUS IG WORKYEARS (146) WILL NOT APPEAR IN FY 1990 TOTALS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1990 MULTI-YEAR BUDGET ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

As directed by the NASA FY 1989 Authorization Law (P.L. 100-685), the following table contains the budget estimates for FY 1990, 1991 and 1992 to implement the President's FY 1990 program:

	1988 ACTUAL	1989 CURRENT ACTUAL	1990 BUDGET ESTIMATE	1991 ESTIMATE	1992 ESTIMATE
RESEARCH AND DEVELOPMENT	3255	4267	5752	7013	7682
SPACE STATION	392	900	2050	2981	3494
SPACE TRANSPORTATION CAPABILITY DEV	593	681	639	693	649
PHYSICS & ASTRONOMY	614	734	895	988	1112
LIFE SCIENCES	72	78	124	154	151
PLANETARY EXPLORATION	328	417	397	470	591
SPACE APPLICATIONS	568	601	580	518	500
SPACE SCIENCE AND APPLICATIONS	1582	1830	1995	2130	2355
TECHNOLOGY UTILIZATION	19	17	23	23	21
COMMERCIAL USE OF SPACE	30	28	38	53	52
COMMERCIAL PROGRAMS	49	45	61	76	73
AERONAUTICAL RESEARCH & TECHNOLOGY	333	404	463	502	531
TRANSATMOSPHERIC RESEARCH & TECH	53	70	127	119	72
SPACE RESEARCH & TECHNOLOGY	221	296	338	430	420
SAFETY, RELIABILITY AND QUALITY ASSURANCE	14	22	23	24	24
UNIVERSITY SPACE SCIENCE AND TECHNOLOGY ACADEMIC PROGRAM	(22)	(22)	35	38	41
TRACKING AND DATA ADVANCED SYSTEMS	18	19	20	21	22
SPACE FLIGHT, CONTROL & DATA COMMUNICATIONS	3806	4464	5140	5171	5516
SHUTTLE PROD & OPERATIONAL CAP	1093	1128	1305	1303	1368
SPACE TRANSPORTATION OPERATIONS	1806	2305	2563	2495	2678
EXPENDABLE LAUNCH VEHICLES	28	86	170	214	242
SPACE & GROUND NETWORK, COMM AND DATA SYSTEMS	879	945	1102	1159	1228
CONSTRUCTION OF FACILITIES	178	275	342	350	350
RESEARCH AND PROGRAM MANAGEMENT	1762	1892	2032	2092	2114
INSPECTOR GENERAL	(7)	(9)	9	9	9
TOTAL NASA	9001	10898	13274	14635	15671

RESEARCH
AND DEVELOPMENT

SUMMARY
INFORMATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

GENERAL STATEMENT

The objectives of the National Aeronautics and Space Administration program of research and development are to extend our knowledge of the Earth, its space environment, and the universe; to expand the technology for practical applications of space technology; to develop and improve manned and unmanned space vehicles; and to assure continued development of the long-term aeronautics and space research and technology necessary to accomplish national goals. These objectives are achieved through the following elements:

SPACE STATION: A program to develop a United States space station to continue the Nation's leadership in space and to provide for enhancement of science and applications programs and to further the commercial utilization of space while stimulating advanced technologies.

SPACE TRANSPORTATION CAPABILITY DEVELOPMENT: A program to provide for the development and use of capabilities related to the Space Shuttle. The principal areas of activity in Space Transportation Capability Development are efforts related to the development and flight certification of the jointly developed U.S./Italy Tethered Satellite System, development of the Orbital Maneuvering Vehicle, development and operations of the Spacelab systems, the development and procurement of upper stages that place satellites in high altitude orbits, the engineering and technical base support at NASA centers, payload operations and support equipment, advanced launch system technology development and study activities, and advanced programs study and evaluation efforts.

SPACE SCIENCE AND APPLICATIONS: A program using space systems, supported by ground-based and airborne observations: (1) to conduct a broad spectrum of scientific investigations to advance our knowledge of the Earth and its space environment, the Sun, the planets, interplanetary and interstellar space, the stars of our galaxy and the universe; and (2) to identify and develop the technology for the useful applications of space techniques in the areas of advanced communications satellite systems technology; materials processing research and experimentation; and remote sensing to acquire information which will assist in the solution of Earth resources and environmental problems.

TECHNOLOGY UTILIZATION: The program includes activities to accelerate the dissemination to both the public and the private sectors of advances achieved in NASA's research, technology, and development program.

COMMERCIAL USE OF SPACE: A program to increase private sector awareness of space opportunities and encourage increased industry investment and participation in high technology, space-based research and development.

AERONAUTICS AND SPACE TECHNOLOGY: A program to conduct the fundamental long-term research and to develop the discipline and systems technology required to maintain United States leadership in aeronautics and space.

SAFETY. RELIABILITY. AND QUALITY ASSURANCE: A program to enhance the safety and technical execution of NASA programs.

TRACKING AND DATA ADVANCED SYSTEM: This program includes activities to perform studies and provide for the development of systems and techniques leading to improve tracking and data program capabilities.

UNIVERSITY SPACE SCIENCE AND TECHNOLOGY ACADEMIC PROGRAM: This program includes activities to support agency-wide university and minority university programs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
RESEARCH AND DEVELOPMENT
FISCAL YEAR 1990 ESTIMATES

	1988 Actual	1989 Revised Budget	1989 Current Estimate	1990 Budget Estimate
	(Millions of Dollars)			
SPACE STATION	392.3	967.4	900.0	2050.2
SPACE TRANSPORTATION CAPABILITY DEVELOPMENT	593.4	631.1	681.0	639.0
SPACE SCIENCE AND APPLICATIONS	1581.8	1859.6	1830.2	1995.3
Physics and astronomy..................	614.4	791.6	734.1	894.5
Life sciences.........................	72.2	101.7	78.1	124.2
Planetary exploration..................	327.7	404.0	416.6	396.9
Earth Sciences........................	389.2	450.4	413.7	434.3
Materials processing...................	62.7	73.4	75.6	92.7
Communications........................	94.8	16.2	92.2	18.6
Information systems...................	20.8	22.3	19.9	34.1
COMMERCIAL PROGRAMS	48.7	57.9	44.7	61.0
Technology Utilization.................	19.0	19.1	16.5	22.7
Commercial use of space................	29.7	38.8	28.2	38.3
AERONAUTICS AND SPACE TECHNOLOGY	606.7	889.5	769.5	927.9
Aeronautical research and technology...	332.9	414.2	404.2	462.8
Transatmospheric research and technology	52.5	84.4	69.4	127.0
Space research and technology..........	221.3	390.9	295.9	338.1
SAFETY, RELIABILITY AND QUALITY ASSURANCE	14.1	22.4	22.4	23.3
UNIVERSITY SPACE SCIENCE AND TECHNOLOGY ACADEMIC PROGRAMS	(21.6)	(22.3)	(22.3)	35.0
TRACKING AND DATA ADVANCED SYSTEMS	17.9	18.8	18.8	19.9
TOTAL	3254.9	4446.7	4266.6	5751.6

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

RESEARCH AND DEVELOPMENT

(INCLUDING RESCISSION OF FUNDS)

For necessary expenses, not otherwise provided for, including research, development, operations, services, minor construction, maintenance, repair, rehabilitation and modification of real and personal property; purchase, hire, maintenance, and operation of other than administrative aircraft, necessary for the conduct and support of aeronautical and space research and development activities of the National Aeronautics and Space Administration; [$4,191,700,000] *$5,751,600,000*, to remain available until September 30, [1990] *1991*, of which [$900,000,000] *$2,050,200,000* is for the [space station program only: *Provided*, That $515,000,000 of the $900,000,000 for the space station program shall not become available for obligation until May 15, 1989, and pursuant to section 202(b) of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, this action is a necessary (but secondary) result of a significant policy change: *Provided further*, That the aforementioned $515,000,000 shall become available unless the President submits a special message after February 1, 1989, notifying the Congress that such funds will not be made available for the space station program.

Of the funds appropriated under this head in the Department of Housing and Urban Development—Independent Agencies Appropriations Act, 1988 (H.R. 2783), as enacted under the provision of section 101(f) of Public Law 100-202, an Act making further continuing appropriations for the fiscal year ending September 30, 1988, $25,000,000 are rescinded] *Space Station Freedom. Further, for the Space Station Freedom, $2,980,500,000 is to be available for obligation on October 1, 1990 and to remain available until September 30, 1992; and further, for the Space Station Freedom, $3,494,400,000 to be available for obligation on October 1, 1991 and to remain available until September 30, 1993: Provided, That for the Space Station Freedom revised baseline, the funds appropriated for U.S. program development will not exceed $13.0 billion in fiscal year 1984 terms, adjusted for inflation and commercial participation. (Department of Housing and Urban Development-Independent Agencies Appropriations Act, 1989; additional authorizing legislation to be proposed.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

REIMBURSABLE SUMMARY
(In thousands of dollars)

	Budget Plan FY 1988	FY 1989	FY 1990
Space station	--	25	25
Space transportation capability development	117,506	105,360	100,175
Space science and applications	369,821	510,795	356,140
Commercial programs	3,304	5,200	5,060
Safety, reliability and quality assurance	2,800	1,400	1,500
Space research and technology	20,169	32,680	25,105
Aeronautical research and technology	68,543	69,250	43,325
Transatmospheric research and technology	1,227	685	135
Energy technolgy	21,420	21,030	21,030
Total	604,790	747,025	552,495

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1990 ESTIMATES

DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Goddard Space Flt Center	Jet Propulsion Lab	Ames Research Center	Langley Research Center	Lewis Research Center	NASA HQ
Space Station	1988	392,300	135,189	10,898	54,701	331	44,304	11,393	1,130	2,553	31,821	99,980
	1989	900,000	328,016	21,609	161,265	50	100,660	9,861	2,883	2,770	121,784	151,102
	1990	2,050,200	885,874	77,379	382,299	100	155,423	25,324	5,774	3,778	301,049	213,200
Space Trans Cap Dev	1988	593,400	121,800	62,500	364,100	9,800	4,200	2,100	1,200	1,100	1,700	24,900
	1989	681,000	145,400	78,400	375,000	5,700	7,900	4,100	---	1,400	2,200	60,900
	1990	639,000	180,200	88,800	290,900	5,800	6,400	1,200	---	1,400	1,800	62,500
Space Sci and Apps	1988	1,581,800	55,929	10,880	281,675	723	443,078	425,449	89,500	19,968	93,280	161,318
	1989	1,830,200	55,895	11,136	239,762	600	640,321	486,182	85,041	23,025	99,505	188,733
	1990	1,995,300	77,527	15,547	229,452	600	799,934	487,243	116,440	24,500	31,347	212,710
Physics and Astronomy	1988	614,400	13,448	7,880	257,020	---	243,352	19,764	13,746	65	56	59,069
	1989	734,100	12,983	8,036	202,328	---	401,717	18,381	15,936	0	50	74,669
	1990	894,500	16,917	11,647	189,002	---	543,084	17,988	25,886	0	500	89,476
Life Sciences	1988	72,200	29,200	3,000	100	100	200	1,100	26,900	500	---	11,100
	1989	78,100	30,700	3,100	100	100	200	1,100	28,700	500	---	13,600
	1990	124,200	47,800	3,900	100	100	200	2,300	50,700	500	---	18,600
Planetary Exploration	1988	327,700	10,828	---	158	---	9,757	247,421	14,757	13	---	44,766
	1989	416,600	9,312	---	134	---	17,870	326,324	15,074	25	---	47,861
	1990	396,900	9,100	---	150	---	17,500	308,950	13,700	---	---	47,500
Earth Science & Apps	1988	389,200	78	---	7,237	508	168,034	126,707	33,129	16,930	---	36,577
	1989	413,700	100	---	10,700	500	203,900	118,600	23,000	18,600	---	38,300
	1990	434,300	100	---	6,800	500	216,500	130,400	19,700	19,800	---	40,500
Materials Proc in Space	1988	62,700	2,375	---	17,160	---	---	19,990	---	2,460	14,425	6,290
	1989	75,600	2,700	---	26,500	---	---	14,500	100	3,900	20,800	7,100
	1990	92,700	3,500	---	29,700	---	---	19,500	200	4,200	24,300	11,300
Communications	1988	94,800	---	---	---	---	7,181	6,187	---	---	78,799	2,633
	1989	92,200	100	---	---	---	3,717	4,220	---	---	78,655	5,508
	1990	18,600	110	---	---	---	3,914	4,642	---	---	6,547	3,387
Information Systems	1988	20,800	---	---	---	115	14,554	4,280	968	---	---	883
	1989	19,900	---	---	---	---	12,917	3,057	2,231	---	---	1,695
	1990	34,100	---	---	3,700	---	18,736	3,463	6,254	---	---	1,947

FISCAL YEAR 1990 ESTIMATES

DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Goddard Space Flt Center	Jet Propulsion Lab	Ames Research Center	Langley Research Center	Lewis Research Center	NASA HQ
Commercial Programs	1988	48,700	2,602	1,036	4,853	5,325	1,450	1,070	1,155	1,215	2,575	27,419
	1989	44,700	4,034	956	1,779	3,720	1,080	955	900	661	883	29,732
	1990	61,000	2,585	1,343	2,604	6,731	2,020	1,135	1,150	2,454	1,575	39,403
Technology Utilization	1988	19,000	2,002	517	646	1,071	1,300	1,070	615	781	365	10,633
	1989	16,500	534	640	185	1,120	940	955	500	661	533	10,432
	1990	22,700	885	682	704	1,231	1,720	1,135	600	1,359	575	13,809
Commercial Use Of Space	1988	29,700	600	519	4,207	4,254	150	---	540	434	2,210	16,786
	1989	28,200	3,500	316	1,594	2,600	140	---	400	---	350	19,300
	1990	38,300	1,700	661	1,900	5,500	300	---	550	1,095	1,000	25,594
Aero & Space Technology	1988	606,700	9,695	402	37,887	---	7,790	31,774	167,777	170,311	123,995	57,069
	1989	769,500	14,000	1,000	45,900	---	7,700	40,600	192,750	209,700	161,360	96,490
	1990	927,900	16,400	700	69,900	---	10,000	49,700	207,600	232,700	186,800	154,100
Aero Research & Tech	1988	332,900	---	---	1,825	---	219	250	139,099	107,988	76,733	6,786
	1989	404,200	---	---	1,800	---	200	300	155,400	142,400	94,900	9,200
	1990	462,800	---	---	[illegible]	---	200	300	169,200	165,000	114,200	10,000
Space Research & Tech	1988	221,300	9,695	402	3 ,002	---	7,571	31,524	24,354	52,435	39,181	20,076
	1989	295,900	14,000	1,000	4 ,100	---	7,500	40,300	32,800	58,500	60,400	37,300
	1990	338,100	16,400	700	6 ,000	---	9,800	49,400	33,400	58,700	66,600	37,100
Transatmos Res & Tech	1988	52,500	---	---	---	---	---	---	4,324	9,888	8,081	30,207
	1989	69,400	---	---	---	---	---	---	4,550	8,800	6,060	49,990
	1990	127,000	---	---	---	---	---	---	5,000	9,000	6,000	107,000
Tracking & Data Acqui	1988	17,900	---	---	---	---	5,400	12,216	---	---	---	284
	1989	18,800	---	---	---	---	5,800	13,000	---	---	---	---
	1990	19,900	---	---	---	---	6,200	13,700	---	---	---	---
University Programs	1988	0	---	---	---	---	---	---	---	---		---
	1989	0	---	---	---	---	---	---	---	---	---	---
	1990	35,000	2,354	985	2,705	823	2,156	1,757	1,247	3,463	1,246	18,264
Safety,Reliability & QA	1988	14,100	2,237	300	1,210	---	621	2,312	420	2,002	1,381	3,617
	1989	22,400	2,600	300	1,575	---	1,488	2,860	450	3,200	1,500	8,427
	1990	23,300	2,500	500	1,800	---	1,900	3,500	500	3,800	2,000	6,800
TOTAL BUDGET PLAN	1988	3,254,900	327,452	86,016	744,426	16,179	506,843	486,314	261,182	197,149	254,752	374,587
	1989	4,266,600	549,945	113,401	825,281	10,070	764,949	557,558	282,024	240,756	387,232	535,384
	1990	5,751,600	1,167,440	185,254	979,660	14,054	984,033	583,559	332,711	272,095	525,817	706,977

SPACE STATION

RESEARCH AND DEVELOPMENT
FISCAL YEAR 1990 ESTIMATES
BUDGET SUMMARY

OFFICE OF SPACE STATION | **SPACE STATION FREEDOM PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Development............................	366,800	935,400	842,000	1,970,200	RD 1-6
Flight telerobotic servicer..............	21,500	20,000	46,000	15,000	RD 1-20
Operations............................	--	--	--	25,000	RD 1-22
Transition definition..................	4,000	12,000	12,000	25,000	RD 1-23
Orbital debris radar....................	--	--	--	15.000	RD 1-25
Total................................	392.300	967.400	900.000	2.050.200	

Distribution of Program Amount by Installation:

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center....................	135,189	354,000	328,016	885,874
Kennedy Space Center....................	10,898	30,000	21,609	77,379
Marshall Space Flight Center.............	54,701	195,200	161,265	382,299
Stennis Space Center....................	331	400	SO	100
Goddard Space Flight Center.............	44,304	80,000	100,660	155,423
Jet Propulsion Laboratory................	11,393	6,800	9,861	25,324
Ames Research Center....................	1,130	300	2,883	5,774
Langley Research Center..................	2,553	400	2,770	3,778
Lewis Research Center...................	31,821	156,000	121,784	301,049
Headquarters............................	99.980	144.300	151.102	213.200
Total..................................	392.300	967.400	900.000	2.050.200

Appropriation of funds necessary for the Space Station program is also requested €or FY 1991 and authorization and appropriation for FY 1992. For FY 1991, the amount requested is $2,980,500,000 to become available for obligation October 1, 1990, and to remain available until September 30, 1992. For FY 1992, the amount requested is $3,494,400,000 to become available for obligation October 1, 1991, and to remain available until September 30, 1993. Total funds for the Space Station Freedom development program will not exceed $13.0 billion in N 1984 terms, adjusted for inflation and private investment.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE STATION | **SPACE STATION FREEDOM PROGRAM**

OBJECTIVES AND JUSTIFICATION

Development of the United States (U.S.) permanently manned Space Station, as directed by President Reagan, will add new momentum to the civil space program and is essential to preserving U.S. preeminence in science, technology and manned space flight. The Space Station Freedom (SSF) program gives us our first opportunity to gain direct experience in long term human operations in space, and knowledge essential to future space exploration. The Space Station will uniquely enhance the U.S. space science programs, further the commercial utilization of space, and stimulate the development and application of advanced technologies of national importance. It is also an avenue of cooperation with our allies, demonstrating the peaceful use of space for the benefit of all.

The SSF will be unique because it will provide the U.S. with a permanently manned presence in space. It will be versatile because its capabilities will be remarkably diverse. This diversity is reflected in the Space Station's design, which features pressurized laboratories, accommodations for attached payloads, and free-flying unmanned platforms. This new national laboratory, a research center in space, will stimulate new technologies, enhance industrial competitiveness, further commercial space enterprises, and add greatly to our storehouse of scientific knowledge. Perhaps the most significant feature of the Space Station, essential to its utility for science, commerce, and technology, is the continuing presence of its crews. Men and women will be aboard the Space Station base full-time. The potential of humans--their creativity--is unique and essential. The Space Station will be designed to exploit the human capabilities. The Space Station's microgravity environment, high levels of power, and extended time in orbit, will enable scientists to make new discoveries in materials research and life sciences. The Space Station's substantive research capabilities include far more than its pressurized volume. Its free-flying platforms will enable truly synergistic studies of the Earth's atmosphere, land masses, and oceans--referred to as Earth system science. These activities will complement the proposed mission to Planet Earth which will help us to understand our environment and aid us in learning to conserve its precious resources. Moreover, the Space Station's external structure is designed to be a stable platform that will be available for mounting a number of specialized instruments and telescopes. Scientific instruments, whether in a laboratory or on a boom, require maintenance, upgrading, repair and replacement. The Space Station will accommodate these servicing functions. The SSF will be designed to evolve, to be capable of growth in its capabilities, so that future needs and challenges can be met.

The SSF will be a multipurpose, international facility. In 1984, President Reagan invited the full participation of other nations. During the ensuing definition phase, Canada, member states of the European Space Agency (ESA), and Japan worked closely with the U.S. to define their participation. These parallel definition and preliminary design studies have resulted in the identification of the Space Station elements to be developed by our partners. Negotiations with these international partners for the development phase of the program were completed in the fall of 1988. Agreements have been signed with the Canadian government for the development of a mobile servicing system and with the member countries of ESA for the inclusion of a pressurized attached module, a man-tended free flyer, and a polar platform. Negotiations with the Japanese government for the development of an attached laboratory module have been completed with formal signing expected in the spring of 1989.

The basic configuration of the SSF and the supporting elements has been arrived at as a result of a lengthy iterative three-year process involving NASA centers, U.S. industry, our international partners, and the national and international science communities. The revised baseline is comprised of a single horizontal boom structure with 75KW of photovoltaic power, the U.S. laboratory and habitability modules, two international laboratory modules (one European and one Japanese), and a Canadian mobile servicing capability. These elements comprise the manned base, and provide internal and external accommodations for the attachment of science and application payloads. There are also two science and applications platforms, one U.S. and one European, to be launched into polar orbit. A man-tended free-flyer is also under consideration by ESA as a co-orbiting platform with the manned base. The launch of the first element is planned for March 1995.

In addition to the development of the manned base and U.S. polar platform, the Space Station program will include development of a Flight Telerobotics Servicer (FTS). The FTS will be a highly automated telerobotic device capable of precise manipulations in space. The FTS on board the Space Station will increase safety and productivity by reducing Extra Vehicular Activity (EVA) time, allowing the use of robotics for hazardous tasks, and freeing crew members for scientific tasks. The FTS will play a key role in the development of automation and robotics (A&R) technologies which will be of benefit not only in space but in ground based applications such as manufacturing. Private sector investment in the FTS is being proposed in order to strengthen private sector involvement in the Space Station program, while at the same time offsetting the need for full Federal funding for development of the FTS.

As noted above, a key design objective of the Space Station is to enable hardware and software to evolve in response to increased user demands and the need for augmented operational capabilities. The Transition Definition activities will provide for systems studies to define options for evolution of the Space Station consistent with future agency missions and for technology development, primarily in automation and robotics, that will enhance the Space Station productivity and private investment in the future Space Station requirements, including those under study. These activities are essential for the long-term cost-effective utilization of the Space Station.

Funding for the development and construction of an orbital debris radar is also provided in this budget request. Monitoring, characterization and assessment of small debris is critical for determining any protective measures needed for incorporation in the Station design. A radar operational in the fourth quarter of CY 1991 is necessary to support the Station critical design reviews in 1992. Studies and preliminary definition for the radar is being provided by the Office of Space Flight.

The Space Station operations encompass all activities required to maintain the Space Station and platforms for their planned lifetime. This includes logistics support, crew training, mission operations, engineering support, launch processing, and user training and operations. Funding for the initial stages of this effort is included in the FY 1990 budget request.

In an ongoing effort to ensure development of the most productive and cost-effective station possible, the SSF program has completed a series of intensive reviews regarding program content and rationale, flight system configuration, and overall reasonableness of the total cost estimate. The most comprehensive review was conducted at the request of President Reagan by the National Research Council's (NRC) Committee on Space Station. The NRC's task was to assess NASA's cost estimates for the Space Station program and to examine the Space Station mission requirements and alternative configurations. This Committee issued its final report on September 10, 1987. The Committee found that the revised baseline configuration was "a satisfactory starting point for the Space Station...and reflects thoughtful compromises among the priorities and sometimes conflicting requirements of its early scientific and engineering users." The Committee also stressed the importance of having a robyst space transportation system, development of an adequate ground test program and backup hardware policy, strengthened Space Station program management, and emphasis on the operational aspects of the program. These recommendations received special attention during the Program Requirements Review (PRR).

During 1988, the SSF program undertook a very thorough and extensive analysis of the program requirements. The purpose of this PRR was to evaluate requirements and to ensure horizontal and vertical consistency in the requirements and in the program documentation. Over six thousand review item discrepancies were surfaced and are being resolved. All of the Space Station program elements, systems, and participants were included. This review reinforced the basic soundness of the current program design.

In FY 1988, the Congress directed a significant reduction in the funding appropriated for the Space Station program in FY 1988. The amount requested by NASA for FY 1988, $767 million, was reduced to $425 million including $100 million transferred from 1987 replacement orbiter production funds. After adjustments for a directed realignment between the research and development appropriation and the research and program management appropriation, the revised plan for FY 1988 was $392.3 million. In FY 1989, NASA requested $967.4 million for the Space Station. As a result of Congressional appropriation action, the Space Station amount was reduced to $900 million. Congressional action further constrained the Space Station program in FY 1989, by allowing for availability of $385 million in new obligational authority until May 15, 1989. The remaining $515 million will become available after May 15, assuming no objection by the President is made after February 1, 1989.

At the request of Congress, NASA prepared and delivered to Congress, in early 1988, a study which assessed the impact of the reduced FY 1988 and FY 1989 funding. At the time of this study, the FY 1989 funding level was assumed to be the $967.4 million which NASA had requested for Space Station. Prior to the reductions in FY 1988 and FY 1989, NASA had planned for a First Element Launch (FEL) in the first quarter of CY 1994. This date was predicated upon a funding level of $767 million in FY 1988 and $1.8 billion in FY 1989. Evaluating the results of the reductions to $425 million and $967.4 million respectively, it was determined that this schedule could not be met and that FEL would need to slip by one year to the first quarter of CY 1995. At the same time, NASA agreed to provide for an early man tended capability on orbit by accelerating the launch of the laboratory module from 1996 to the fourth quarter of CY 1995. The above schedule assumes receipt of the requested funding of $2,050.2 million for FY 1990.

This budget requests appropriations for the Space Station of $2,050.2 million for FY 1990, and $2,980.5 million for FY 1991, and the authorization and appropriation of $3,494.4 million for FY 1992. During the FY 1989 budget process, the Administration requested similar legislation for a Congressional commitment to a three year authorization and appropriation of Space Station funds for FY 1989, FY 1990 and FY 1991 in an amount totalling $6,010.1 million. This request was included in the NASA 1989 authorization bill passed by Congress and signed by the President. Continuation of these measures on the part of Congress and the Administration will provide increased program stability while maintaining cost control discipline for both development and operations. In addition, the Administration plans to request legislation to establish a total development program cost ceiling of $13 billion, in FY 1984 constant dollars adjusted for inflation and private investment. These commitments will help assure international participants of the U.S. commitments to SSF development and recognizes the importance of their cooperation on the Space Station program.

In support of the President's policy on the commercial use of space, NASA, in consultation with the OMB, recently released drafts of revised guidelines, policy, procedures and criteria for industry comment. These guidelines on the commercialization of the Space Station will serve to reaffirm, clarify and strengthen its commitment to private sector investment and involvement in the Space Station program. NASA will give positive consideration to proposals to accelerate private sector investment in Space Station development and operations in the form of either goods or services which have not yet been contracted. Further, NASA will actively pursue approaches to encourage the private sector to invest in the FTS the Space Station docking system and future requirements for the Space Station, including those under study, e.g., solar dynamics power and equipment to utilize the Space Station.

BASIS FOR FY 1990 FUNDING REQUIREMENT

DEVELOPMENT

	1988 Actual	1989 Budget Estimates	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Management and integration...............	146,700	169,400	187,700	230,200
Pressurized modules.....................	55,000	188,000	155,500	366,000
Assembly hardware/subsystems.............	82,000	288,000	263,200	762,000
Platforms and servicing..................	26,000	56,000	51,200	130,000
Power system............................	31,000	154,000	120,000	298,000
Operations/utilization capability........	26.100	80.000	64.400	184.000
Total..................	366,800	935,400	842.000	1.970.200

OBJECTIVES AND STATUS

As a research facility in space, the SSF will provide opportunities for significant advances in science, technology and commerce. It must be flexible yet durable in its capabilities, as the Station will be on orbit for many years. It must be operationally affordable for its success will be measured by its operational utility. The objectives of the program are: (1) to establish a permanently manned research facility in low-Earth orbit in the mid-1990's with the capability to evolve to meet future potential requirements; (2) to enhance mankind's evolving ability to live and work safely in space; (3) to stimulate technologies of national importance (especially automation and robotics) by using them to provide needed capabilities; (4) to provide cost-effective operation and utilization of continually improving facilities for scientific, technological, and operational activities enabled or enhanced by the presence of man in space; (5) to foster mutually beneficial international cooperation in space; (6) to create and expand opportunities for private sector activity in space; (7) to enable the evolution of the Space Station to meet future potential requirements and challenges; and, (8) to provide unmanned platforms exploiting station systems and subsystems design for long duration scientific and operation observations. The combination of manned, unmanned, and automated systems will establish a broad spectrum of capabilities responsive to both currently identified and evolutionary needs of space science, technology, and commerce.

Following completion of a three-year definition and advanced technology development phase, the development program was initiated in FY 1987. The selected revised baseline configuration includes a permanently manned Space Station, unmanned platforms, and the associated ground-based infrastructure. The major physical elements of the configuration to be developed by the U.S. include pressurized habitation and laboratory modules, with a shirt-sleeve environment for crew habitation and for conducting experiments under microgravity conditions; resource nodes linking the modules in which command and control, docking and extravehicular activity (airlocks) functions will be based; high power solar arrays; a truss structure featuring accommodations for attached payloads and the FTS; pressurized and unpressurized logistics elements; extravehicular capabilities; and, a polar platform carrying Earth observing system instruments to be developed under the Space Science and Applications program. The configuration includes elements provided by the program's international partners. These elements are the Japanese experiment module, which includes a pressurized laboratory, an exposed module for payloads, and a logistics module; the Canadian Mobile Servicing System; and, the ESA's pressurized laboratory, polar platform, and man-tended free-flyer. The Space Station will be able to support a crew of eight and provide a total average power of not less than 75 kilowatts, using photovoltaic arrays.

The ground-based infrastructure needed for the development and operation of the Space Station include the development of capabilities for systems engineering and integration, a distributed system for technical and management information transmission, software development tools, prelaunch processing, mission operations, engineering support, integrated testing, and payload operations support.

The management of U.S. Station Space hardware elements design and development is led by four NASA field centers. The Space Station Program Office (SSPO), located in Reston, Virginia, has the task of managing and integrating the technical development of the entire program. The four "work package" centers are the Marshall Space Flight Center (MSFC) in Huntsville, Alabama; the Johnson Space Center (JSC) in Houston, Texas; the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland; and the Lewis Research Center (LeRC) in Cleveland, Ohio. While not work package centers, the Kennedy Space Center (KSC) at Cape Canaveral, Florida and the Langley Research Center (LaRC) in Hampton, Virginia have key Space Station responsibilities. KSC has the responsibility for Space Station prelaunch processing and post-landing activities plus a major role in logistics and user integration support while LaRC provides major support in systems engineering and integration. The Jet Propulsion Laboratory (JPL) in Pasadena, California, will also play a central role in defining Space Station program requirements and conducting independent assessments. NASA's development strategy for the Space Station deliberately precluded utilization of a single prime contractor. For a program of such extended duration as the Station, dependency upon one company was not viewed as being in the best interest of the government. Moreover, the work package approach better utilizes NASA expertise at the field centers and fosters greater competition among U.S. industry. An essential component of this strategy is that NASA will have the responsibility to perform the overall systems engineering and integration and program management. The SSPO is being assisted in these program-wide integration functions by a Program Support Contractor (PSC), a Software Support Environment (SSE) contractor and a Technical and Management Information System (TMIS) contractor.

In 1987, the development contractors for the Space Station were selected. In May 1987, Boeing Computer Services was selected for the TMIS contract. This contract will facilitate both program control and engineering by enabling the electronic transmission of information and providing a means of distributing, and laboratory modules, with a shirt-sleeve environment for crew habitation and for conducting experiments under microgravity conditions; resource nodes linking the modules in which command and control, docking and extravehicular activity (airlocks) functions will be based; high power solar arrays; a truss structure featuring accommodations for attached payloads and the FTS; pressurized and unpressurized logistics elements; extravehicular capabilities; and, a polar platform carrying Earth observing system instruments to be developed under the Space Science and Applications program. The configuration includes elements provided by the program's international partners. These elements are the Japanese experiment module, which includes a pressurized laboratory, an exposed module for payloads, and a logistics module; the Canadian Mobile Servicing System; and, the ESA's pressurized laboratory, polar platform, and man-tended free-flyer. The Space Station will be able to support a crew of eight and provide a total average power of not less than 75 kilowatts, using photovoltaic arrays.

The ground-based infrastructure needed for the development and operation of the Space Station include the development of capabilities for systems engineering and integration, a distributed system for technical and management information transmission, software development tools, prelaunch processing, mission operations, engineering support, integrated testing, and payload operations support.

The management of U.S. Station Space hardware elements design and development is led by four NASA field centers. The Space Station Program Office (SSPO), located in Reston, Virginia, has the task of managing and integrating the technical development of the entire program. The four "work package" centers are the Marshall Space Flight Center (MSFC) in Huntsville, Alabama; the Johnson Space Center (JSC) in Houston, Texas; the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland; and the Lewis Research Center (LeRC) in Cleveland, Ohio. While not work package centers, the Kennedy Space Center (KSC) at Cape Canaveral, Florida and the Langley Research Center (LaRC) in Hampton, Virginia have key Space Station responsibilities. KSC has the responsibility for Space Station prelaunch processing and post-landing activities plus a major role in logistics and user integration support while LaRC provides major support in systems engineering and integration. The Jet Propulsion Laboratory (JPL) in Pasadena, California, will also play a central role in defining Space Station program requirements and conducting independent assessments. NASA's development strategy for the Space Station deliberately precluded utilization of a single prime contractor. For a program of such extended duration as the Station, dependency upon one company was not viewed as being in the best interest of the government. Moreover, the work package approach better utilizes NASA expertise at the field centers and fosters greater competition among U.S. industry. An essential component of this strategy is that NASA will have the responsibility to perform the overall systems engineering and integration and program management. The SSPO is being assisted in these program-wide integration functions by a Program Support Contractor (PSC), a Software Support Environment (SSE) contractor and a Technical and Management Information System (TMIS) contractor.

In 1987, the development contractors for the Space Station were selected. In May 1987, Boeing Computer Services was selected for the TMIS contract. This contract will facilitate both program control and engineering by enabling the electronic transmission of information and providing a means of distributing, maintaining, and archiving controlled data throughout the program. In July 1987, Grumman Aerospace was selected as the PSC. Grumman and its team supports NASA in a variety of areas, including systems engineering and analysis, distributed systems integration, technical integration, element and launch package integration, user interface planning, and program management and control. Also in July, 1987, the Lockheed Missiles and Space Company was selected for the SSE system contract. The SSE system is designed to assure a standardized software development and maintenance environment, in order to minimize the development and cost risk inherent in the task of integrating flight and ground systems software developed by a variety of Space Station contractors. On December 1, 1987, NASA announced selection of four aerospace firms--Boeing Aerospace Company; McDonnell Douglas Astronautics Company; General Electric Company; and the Rocketdyne Division of Rockwell International--for final negotiations leading to award of contracts for the design, development and support of the components and systems comprising the permanently manned Space Station. Letter contracts were awarded to these four companies on December 23, 1987 and the final detailed contracts were signed September 28, 1988. During the letter contract period, the contractors began planning for the initiation of their respective work package preliminary design and development efforts. They also supported the work package centers in the evaluation of the PRR and participated in the planning and working groups that have been formed to allow the various program elements and participants to share information. Due to the complexity of this enormous effort, it soon became apparent that a mechanism was needed which would allow the contractors to work together to achieve the common goal of building the Space Station to specifications, on schedule, and within the available funding. To satisfy this need, the Space Station program instituted associate contractor agreements among the contractors. They will have the responsibility, with NASA work package center and SSPO oversight, for coordinating the integration of their efforts in a timely and cost-effective manner and for delivering to NASA the required integrated hardware and software.

The development program also includes critical supporting development activities at the four NASA work package centers, and the development of the capability to operate and utilize the Space Station. Work package supporting development includes design engineering, hardware integration and test capabilities, and assembly and checkout test capabilities; the provision of Government Furnished Equipment (GFE); research and development (R&D) facility outfitting; and, engineering management and analysis. These efforts support all of the work package prime contractors as well as overall NASA system engineering and integration efforts. The Operational and Utilization Capability Development (OUCD) activities support major operational facility development at the NASA work package centers and KSC. These facilities are critical to the integration, prelaunch/post-landing processing, and the missions operations and crew training of the Space Station systems.

Due to budgetary reductions and constraints made by Congress in the FY 1988 and FY 1989 appropriation processes, Space Station development activities will build up at a slower pace than originally planned. The Space Station Preliminary Design Review (PDR), which will provide an evaluation of the design approach of the work packages, will slip from FY 1989 to FY 1990. Successful completion of the PDR will result in the readiness to proceed with detailed design of the SSF flight and ground hardware and software. The Critical Design Review (CDR) is currently planned to occur in FY 1992. The first element launch is planned for March of 1995, man-tended capability in the fourth quarter of 1995, permanent manned capability planned in the fourth quarter of 1996, and assembly complete in the first quarter of 1998.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Management and integration...............	146,700	169,400	187,700	230,200

OBJECTIVES AND STATUS

Elements of the SSF are being designed and developed by NASA centers and contractors throughout the U.S. as well as by the Canadians, Europeans, Japanese, and their contractors. Coordinating and integrating all of these various activities requires a comprehensive management and integration program effort by the SSF Program Office (SSFPO). Management responsibilities include: overall .program management and direction; systems engineering and design; management of technical and administrative information; systems software environment design and development; safety, reliability, maintainability, and quality assurance activities; and integration of the United States and international systems and elements.

The broad scope and large magnitude of the Space Station program requires that NASA be supported by contractors knowledgeable in overall systems design, engineering, and integration. To achieve this goal NASA undertook a competitive procurement and in FY 1987 awarded a program support contract (PSC) to Grumman Aerospace Corporation, Bethpage, New York. Grumman is supporting not only the SSFPO in Reston, Virginia, but will also have personnel resident at the work package centers to assist them in their program integration activities. As the program support contractor, Grumman has responsibility for supporting overall Space Station systems engineering and integration activities. This includes providing the engineering manpower necessary for total systems configuration analysis and integration, design trade-offs, and operational analyses. They also assist in evaluation of technical performance across the program and perform program schedule integration. The PSC develops technical plans and procedures for the verification, assembly, and integration of the overall Space Station system and assists in the assessment of hardware/software systems developed by the work package prime contractors.

During FY 1989 the PSC will provide support for the completion and implementation of studies and analyses resulting from the PRR which was conducted during mid FY 1988. They will also be heavily involved in all of the activities necessary for supporting the Preliminary Design Review (PDR) for the man-tended configuration. This PDR is scheduled for late FY 1990. Implementation of a program-wide technical and management information system (TMIS) is a significant part of the management and integration activity.

The size and complexity of technical and management information that must be shared across all elements and levels of the SSFO requires the development of an advanced information system that can expeditiously handle the flow of this data. In June 1987, Boeing Computer Services was awarded a systems integration contract to provide TMIS. TMIS is the official repository of technical and management information throughout the life of the SSFP. It provides a common methodology for tracking, updating, and disseminating SSFP documentation. TMIS facilitates and provides electronic transfer of a variety of program data among all the participating NASA centers and contractors. It will also allow NASA to electronically transfer appropriate program data to compatible information systems of the international participants. The initial increment of TMIS hardware and software was delivered in June 1988, and most recently, the initial hardware to house data bases was installed.

Another important component of the management and integration effort is the design, development, and application of compatible flight and ground support software. To ensure compatibility across the various elements of the Space Station information system, NASA awarded a contract to the Lockheed Missiles and Space Company for the development of a software support environment (SSE). Lockheed is tasked to develop the software tools, rules, and standards that will be common to all Freedom Station flight and ground support users in their software development efforts. SSE has developed the initial SSE Development Facility (SSEDF) which is providing SSE equivalent basic software life cycle support capability to available main frame computer hardware. Currently, SSE has started developing prototype simulation interface buffers (SIB) which are software controlled multiport interface systems used to interface SSE host computers with data management system (DMS) kit flight system hardware. The contractor is also in the process of delivering seven software production facilities and will be bringing them on line to support the preliminary and critical design reviews.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Management and integration has increased from $169.4 million to $187.7 million, an increase of $18.3 million over the FY 1989 budget request. The increase in management and integration was partly due to increases in the contractor support to provide necessary program integration and system engineering support during the time leading to finalization of the PRR and preparation for the PDR. There has also been an increase in the amount of activity being undertaken to support the program with more intensive efforts in user interface and operations planning. Staffing has also increased at JPL for the program requirements and assessment function which provides the program office with an independent assessment of the program requirements. This effort becomes particularly important during FY 1989 as the program requirements become baselined and the preliminary design efforts accelerate. Finally, there has been an increase in the Space Station usage requirements of the NASA Program Support Communications Network.

BASIS OF FY 1990 ESTIMATE

A key management and integration activity occurring in FY 1990 will be the evaluation of project level system and element PDRs. These PDRs will be the basis for the program level PDR for the man-tended capability to be held in late FY 1990. PSC will be assisting NASA in this effort as well as in developing integrated schedules, verification plans, interface control documentation, and engineering data bases. Also during this period, the PSC will provide engineering support to the development of program plans for launch package integration, on-orbit assembly and checkout, NSTS integration, design reference mission and mission integration, and system safety and quality assurance program planning. This critical system engineering effort will be in support of the Reston SSPO, the Program Integration Offices at each work package center and at KSC.

During FY 1990, the SSE will achieve its initial operational capability and be delivered to the multi-system integration facility. The SSE project will complete development of the first simulation interface buffer (SIB). Subsequently, data management system (DMS) kits including SIB and DMS hardware, provided by Work Package 2, will be installed in the SSEDF so that full development and testing of SSE integration, test and verification capabilities can proceed. To further the development of the SSE operational system, the functional simulator (FSIM) will start to provide a capability for Space Station Program software developers to simulate the Space Station DMS system software services.

TMIS will continue to incrementally deliver releases of its products and will be working closely with all levels of the program to assure the most efficient and comprehensive exchange of information. Efforts will continue towards completion of the various bridges needed to electronically link together the contractors, NASA centers, users, and international partners as well as provide training to TMIS users as the system evolves. Technical and resource information management and tracking systems and data bases will continue to be developed with emphasis in Increment 2 on the efforts needed to support the SSFPO PDR process. Increment 2 will focus on completing TMIS rules and procedures, stabilizing and refining Increment 1 tools, providing a significant increase in data base and electronic mail host capacity, integrating data bases containing both technical and management data, and providing the first delivery of computer aided design/computer aided engineering (CAD/CAE) capability for the program. Increment 3 efforts will be targeted toward the development of applications and capabilities needed to support the SSFPO CDR process.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Pressurized modules - work package 1, Marshall Space Flight Center...........	55,000	188,000	155,500	366,000

OBJECTIVES AND STATUS

Work Package 1 is being managed by MSFC, Huntsville, Alabama with support from its prime contractor, Boeing Aerospace Corporation. Boeing was awarded a letter contract on December 23, 1987 and signed a negotiated contract on September 28, 1988. Assisting Boeing as major members of the prime contract team are Teledyne Brown Engineering (Huntsville, Alabama), Lockheed Missiles and Space Company (Sunnyvale, California), Hamilton Standard (Windsor Locks, Connecticut), Allied Signal Aerospace (Torrance, California), Grumman Aerospace Corporation (Houston, Texas), ILC Space Systems (Houston, Texas), and Fairchild-Weston Systems (Syossett, New York).

Major components of this package include the U.S. laboratory, habitability, and logistics modules; nodes structure; airlock systems; environmental control and life support system; internal audio, video, and thermal systems; basic module outfitting; and associated software development.

Since the initiation of the development phase of the Space Station Freedom (SSF) program, emphasis has been placed on the preparation of the plans and procedures that will be needed to design, develop, build, test, integrate, launch, and operate the Station. Included in these activities are the development of the engineering breadboards, trade studies, hardware build, and technology demonstration of the environmental control and life support system; design and development of the module mock-ups; and evaluation of computerized structural models of the module components. Also ongoing is the evaluation of critical materials to be used in and on the Station and the design and development of computerized data bases that will be used to track and analyze the extensive test and evaluation results. As is the case with developing programs, much of the initial activity is in preparing the planning documents that will guide the development through its various stages. These plans and procedures are currently in the process of being baselined and will be updated as needed throughout the life of the Space Station program. With the recent completion of the PRR, efforts will now proceed toward implementation of the preliminary design leading toward the preliminary design review in FY 1990.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The previous FY 1989 budget of $188 million has been reduced to $155.5 million, a decrease of $32.5 million, primarily as a result of reduced Space Station funding appropriated by Congress and a reprioritization of development activities by the program office. This reduction is being accomplished by deferring the preliminary and critical design review dates, deferring the buildup of prime contractor and subcontractor manpower, and limiting supporting development manpower hiring and equipment purchases.

BASIS OF FY 1990 ESTIMATE

FY 1990 is a significant year for Work Package 1 because it is the year in which preliminary design reviews are planned to take place for all the major systems and elements needed for man-tended capability. Upon completion of these preliminary design reviews, prime contractor efforts will begin on the final design leading to critical design reviews in FY 1991 and FY 1982. The environmental control and life support system comparative technology testing which began in FY 1989 will continue and efforts will begin on the testing in the Core Module Integration Facility (CMIF). In the area of resource nodes and airlock systems, work will begin or continue on the support equipment component testing, cupola preliminary design, tool and production planning, and material procurement for structural test articles. The U.S. laboratory engineering development article will be completed'and development hardware and software fabrication and test will begin. Work will continue on the preliminary design of the habitation module unique functions as well as preparation for and support of formal customer reviews. During FY 1990, there will be a review of all cargo requirements for the logistics modules as well as development of the concepts for accommodation of specimen, carriers, and subsystems. Work will continue on the development tests for logistics unique hardware and on defining the interfaces unique to the logistic modules with the orbiter, the station, and the cargo.

In the area of supporting development, system testing will continue utilizing the process material management system breadboard, the audio/video breadboard, and the electrical power system breadboard. Integrated environmental control and life support system testing will be completed and the node structural test article critical design review will be held leading to the start of fabrication. By the end of FY 1990, most of the developmental testing will be completed and hardware builds by the prime contractor will be initiated.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Assembly hardware/subsystems - work package 2, Johnson Space Center........	82,000	288,000	263,200	762,000

OBJECTIVES AND STATUS

Work Package 2 is managed by JSC with support from the prime contractor, McDonnell Douglas Corporation. The letter contract for this effort was awarded to McDonnell Douglas on December 23, 1987, and the final negotiated contract was signed on September 28, 1988. Assisting McDonnell Douglas as major members of the contract team are IBM (Houston, Texas and Owego, New York), Lockheed Missiles and Space Company (Houston, Texas and Sunnyvale, California), General Electric/RCA Corporation (Camden, New Jersey), Honeywell (Clearwater, Florida), and Astro Aerospace Corporation (Carpinteria, California).

Work Package 2 responsibilities include the integrated truss assembly, mobile transporter, airlock structure and unique equipment, outfitting of the resource nodes, and the propulsion system. Also included in Work Package 2 are the data management system, communications and tracking; guidance, navigation and control, extra vehicular activity systems, thermal control, mechanical systems, fluids, and utilities distribution.

Much of the effort taking place since letter contract inception has been in formulating the plans, procedures, and design concepts that will be utilized for the development of the Work Package 2 elements and systems. The recently completed PRR lays the groundwork for finalizing the program requirements and efforts are now underway to baseline these requirements and proceed toward their implementation. Work is currently underway and progressing toward the development of test beds needed to evaluate design concepts, design and trade studies, facility requirements, and subsystem requirements. JSC personnel have been working with the Canadians to coordinate their mobile servicing center with the mobile transporter. Work is also progressing on design of the Space Station Extravehicular Mobility Unit with a prototype suit to be evaluated during FY 1989. Plans for the procedures, hardware, and software needed for on-orbit assembly are continuing and Shuttle/Station berthing and docking concepts are being investigated and tested. Also ongoing is the design and development of the flight experiments that will be needed to test various concepts and hardware prior to their use on the SSF. These flight experiments will, among other things, test thermal systems, guidance, navigation, and control, and the Space Station EVA suit.

CHANGES FROM FY 1989 BUDGET ESTIMATE

As a result of reduced funding appropriated by Congress and reprioritization of development activities, the current budget for FY 1989 is $263.2 million, a reduction of $24.8 million from the previous budget request of $288 million. This reduction will be accomplished by rephasing intermediate milestones such as the preliminary and critical design reviews, and by constraining the buildup of contractor manpower and the purchase of some materials.

BASIS OF FY 1990 ESTIMATE

The major milestone in FY 1990 is the preliminary design review of the systems and elements needed for man-tended capability. JSC and its contractors will be holding project design reviews for its elements and systems during the third quarter of the fiscal year in preparation for the program design review planned for the fourth quarter. There is a great deal of design, analysis, and test work that must be performed prior to these reviews. Much of this effort will have been initiated in FY 1989 but will become more intensive during 1990. The prime contractor will finish preliminary design work and begin the task of detailed design. Development testing will continue and work will begin on the procurement, fabrication, and assembly of the data management system hardware and software, the thermal control system, the mobile transporter, and the airlocks. The prime contractor will also continue to support the various working groups and panels that are responsible for coordinating the efforts of the program participants and will perform studies as directed by JSC and the SSPO.

JSC will also continue its supporting development efforts in preparation for the preliminary design review. They will begin integrated loads/dynamics truss analysis and thermal vacuum chamber solar outfitting. Verification tests will be performed on the antennas and work will continue on the prototype electrolysis unit fabrication and test. Efforts will continue in preparation for thermal flight experiments and refinements and testing of the AX5/Mark III space suits should be completed. In addition, utilizing the KC-135 airplane, tests that require a space-like environment will be performed.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Platform and servicing - work package 3, Goddard Space Flight Center.	26,000	56,000	51,200	130,000

OBJECTIVES AND STATUS

Work Package 3 is being managed by GSFC, Greenbelt, Maryland with support from its prime contractor, The General Electric Company, Astrospace Division, Valley Forge, Pennsylvania, and East Windsor, New Jersey. General Electric was awarded a letter contract on December 23, 1987, and signed the negotiated contract on September 28, 1988. The TRW Corporation of Redondo Beach, California, is the major subcontractor to General Electric.

Included in Work Package 3 is the design and development of the free-flying, unmanned U.S. polar platform; the attached payload accommodation equipment (APAE) for the mounting of various scientific instruments on the manned base; and a payload pointing system (PPS) for both Earth-viewing and space-viewing attached payloads that require a high degree of accuracy. Also included are early studies of the design, requirements, and interfaces necessary for a satellite servicing facility that could be used to service SSF payloads and free-flying spacecraft. Development of a servicing facility is a potential future consideration. A key component of this work package is an ongoing interaction with potential users of the Space Station. Understanding the needs of potential Space Station users and including them in all of the pertinent planning activities is vital to the design, development, and operation of the station.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The budget for Work Package 3 was reduced by $4.8 million from the previously budgeted amount of $56 million to the current budget of $51.2 million, as a result of reduced Space Station funding appropriated by Congress and reprioritization of development activity. This decrease was accomplished by rephasing interim milestones and by deferring some supporting development technical activities.

BASIS OF FY 1990 ESTIMATE

A major activity taking place at Work Package 3 during FY 1990 is the PDR for the polar platform. Upon successful completion of the PDR, detailed design, testing, long-lead procurement, and fabrication of the platform will begin. Preliminary design and requirements definition of the attached payload accommodation equipment and the payload pointing system will continue during FY 1990. Studies of servicing facility architecture will continue, and servicing scenarios for selected payloads will be developed.

Supporting development activities at GSFC will include continuing engineering and discipline support for the platform, APAE, and PPS. Base motion studies for the PPS will be conducted. Discipline support for the safety, reliability, and quality assurance area will continue. As part of the thermal program, development of a data management system test bed, an instrument test bed, and NSTS thermal flight test experiments will continue. Design and requirements definition for an Integration, Test, and Verification Facility at the GSFC will be initiated. This facility will provide a clean environment for the checkout of the attached payloads and the polar platform with the physical, electrical, and thermal interfaces.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Power system - work package 4, Lewis Research Center........................	31,000	154,000	120,000	298,000

OBJECTIVES AND STATUS

Work Package 4 is managed by the LeRC and supported by its prime contractor, Rocketdyne Division, Rockwell International (Canoga Park, California). Supporting Rocketdyne as major members of the contract team are Ford Aerospace (Palo Alto, California); Harris Corporation (Melbourne, Florida); Allied-Signal Aerospace Corporation (Tempe, Arizona); General Dynamics Corporation (San Diego, California); and Lockheed Missiles and Space Company (Sunnyvale, California). Rocketdyne was awarded a letter contract on December 23, 1987, and signed the negotiated contract on September 28, 1988.

The primary content of Work Package 4 is the SSF Electrical Power System. This encompasses the development of a 75 KW photovoltaic (PV) power system which uses solar arrays to collect power and batteries for storage; the power management and distribution (PMAD) system; engineering and system architecture of a solar dynamic power system capability which could be a future addition to the station; and the fabrication of power system components for the polar platform.

The electric power system will be one component of the first element launch and therefore hardware must be ready for delivery at that point in the program. System and sub-system design and development are actively being performed by the contractor team and by the Lewis supporting development personnel. Component testing of the batteries and solar cells began in FY 1988 and will continue into FY 1989 in preparation for the preliminary design review in FY 1990. Test beds for both photovoltaic power and the power management distribution system have been developed and are being utilized. The Power System Facility and the Space Power Facility are in the process of being made ready to begin testing and work has commenced on developing an integrated test bed. Work is also proceeding in preparation for proof-of-concept testing of the solar dynamic power system.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The FY 1989 budget for Work Package 4 has been reduced by $34 million from the previous budget submission of $154 million as a result of reduced Space Station funding appropriated by Congress and reprioritization of development activity. This reduction has been accomplished primarily by deferring intermediate milestones such as preliminary and critical design reviews and delaying hardware deliveries to the other work packages.

BASIS OF FY 1990 ESTIMATE

During FY 1990 efforts being performed by the prime contractor and LeRC teams will intensify in preparation for the project and program preliminary design reviews. Rocketdyne will continue with development and qualification of the solar cells and blankets. Energy storage assembly qualification cells will be fabricated and tested. Preliminary and detailed design of module items such as beta gimbals and electrical equipment assemblies will continue as will the preliminary design effort for the solar dynamic power. Power management and distribution components and orbital replacement units will undergo preliminary and then detailed design during FY 1990 and development and testing of breadboard and brassboard components will continue.

Supporting development activities complement those being performed by the contractor and include the independent verification of the prime systems engineering and integration efforts. Also included in supporting development is the design and provision of the interfaces with the SSE and the Space Station Information System. Key work will continue utilizing the existing PV/PMAD testbed and the PMAD systems testbed and efforts will begin on preparation of the integrated testbed. These test and evaluation activities will culminate in the development of a preliminary design which will then be reviewed in the latter part of FY 1990 as part of the overall program preliminary design review.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Operations/utilization capability development...........................	26,100	80,000	64,400	184,000

OBJECTIVES AND STATUS

The purpose of the Operations/Utilization Capability Development (OUCD) program is to develop a set of operational facilities, systems, and capabilities to conduct the operations of the SSF. The majority of the work will be performed at KSC, MSFC, and JSC, although key operational capabilities will be developed at other NASA centers. KSC will develop launch site operations capabilities for conducting prelaunch and post-landing ground operations for the SSF. These capabilities will include the development of the Test, Control and Monitor System (TCMS) to provide real-time checkout, control and monitoring functions during processing of SSF elements at KSC and the Vandenberg Launch Site (VLS) prior to launch. Prelaunch and post-landing ground operations will occur in the Space Station Processing Facility (SSPF) and other key facilities, including the Space Station Hazardous Processing Facility (SSHPF) at KSC and the Platform Processing Facility at Vandenberg.

MSFC will develop user integration capabilities to establish user requirements and perform user operations support. Efforts will include the development of the Payload Operations Integration Center (POIC) and the Payload Operations Training Facility (POTF), as well as extensive payload mission planning and analytical integration. The major objective at JSC is to develop space systems operations capabilities for conducting training and on-orbit operations control of the SSF. Efforts will include the development of the Space Station Control Center (SSCC), the Space Station Training Facility (SSTF), and the Operations Planning and Analysis System (OPAS). LeRC will provide an Engineering Support Center (ESC) for the power system, and GSFC will provide an ESC for attached payloads and special outfitting for the Platform Control Center. Each of these centers will be involved in user integration activities and operations planning efforts.

Work is currently underway to develop facility requirements and outfitting needs and to develop the mission planning and user interfaces. The prime contractors associated with the four work packages are assisting in these activities since the design, development, and operation of the station are so strongly interconnected. User input is being solicited and received and users are being kept informed of progress in all of the OUCD planning efforts. Astronauts are also included in this process and their input is an important part of the design and operations activities. Requests for Proposals have been released for the Control Center and Training Facility support at JSC and for the TCMS at KSC.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The FY 1989 budget was reduced by $15.6 million, from $80.0 million to $64.4 million, as a result of reduced Space Station funding appropriated by Congress and reprioritization of development activities. This reduction has been taken by rephasing milestones and delaying the purchase of equipment such as Computer Aided Design/Computer Aided Engineering (CAD/CAE). Also, the buildup of manpower at KSC will be slowed, as will the manpower buildup for increment design and planning efforts at JSC.

BASIS OF FY 1990 ESTIMATE

At KSC in FY 1990, the CAD/CAE contract and the TCMS avionics procurement will begin, and the PDR for the core design of the TCMS will be conducted. The procurement of ground support equipment for the SSPF will continue. At MSFC, design of the POIC and the POTF will continue, as will development of analytical integration software tools. Engineering studies for the POTF core computer will be completed and procurement initiated. At JSC, requirements definition and design of the SSCC and the SSTF will continue. The PDR will be held for the SSCC, and for the OPAS. LeRC and GSFC will continue design of their ESCs, and GSFC will continue platform and attached payload analyses and user accommodation studies.

BASIS OF FY 1990 FUNDING REOUIREMENT

FLIGHT TELEROBOTICS SERVICER

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Flight telerobotics servicer............	21,500	20,000	46,000	15,000

OBJECTIVES AND STATUS

The Flight Telerobotics Servicer (FTS) will be a highly automated, robotic flight system capable of precise manipulations in space. It can be operated by astronauts at work stations aboard the space station or the shuttle by either direct manipulator control or programmed command sequences. Its hardware and software will be modular to ensure serviceability, and its configuration will be flexible to accommodate technological upgrades and growth to autonomous operation. The FTS will be capable of performing EVA tasks such as assembly, inspection, maintenance, and servicing. By reducing dependence on EVA, it will improve crew safety and enhance crew utilization. The FTS will be designed to attach to several hardware elements, such as the Shuttle's Remote Manipulator System; utility ports along the SSF truss; the Orbital Maneuvering Vehicle; and SSF platforms. The knowledge NASA gains using the FTS in space will be used to facilitate the transfer of automation and robotics (A&R) technology to U.S. industry.

The FTS is being proposed as a commercial development. Project management is the responsibility of GSFC, with support from other NASA centers and contractors. The major elements of the program include the Space Station FTS (SSFTS), or telerobot flight unit, which will be available at FEL, and will be launched on the second assembly flight; the Development Test Flight (DTF-1); the Demonstration Test Flight (DTF-2); and the Engineering Test System (ETS). Supporting development activities at GSFC and other NASA centers will identify and utilize developing automation and robotics technologies to meet FTS requirements and improve FTS performance and will support the transfer of demonstrated capabilities and technology concepts to commercial applications.

The DTF-1 is planned to be flown aboard the NSTS in late 1991 and will consist of two telerobot manipulators, a carrier structure, task elements, and a workstation. Using existing technology, DTF-1 will evaluate FTS design approaches and man-machine interfaces. In September 1988, nine-month letter contracts for $4.5 million each were awarded to the Martin-Marietta Corporation and to Grumman Aerospace for preliminary design of DTF-1. These contracts provide for initiation of long-lead procurement items and for delivery of all analyses and documentation required to support a PDR for DTF-1, currently planned to be held in mid-1989. The DTF-2 will consist of a mature version of the SSFTS, a carrier structure, task elements, flight support equipment, and a workstation, to be flown aboard the NSTS in early 1993. DTF-2 will demonstrate FTS capabilities prior to SSF deployment.

The ETS will be a ground test system for FTS software development and verification; for dexterous task planning and verification; and for flight anomaly investigation. It will consist of a telerobot, multipurpose end-effectors and tools, ground support equipment, and spares.

In September 1988, the FTS Phase B contracts with Martin-Marietta and Grumman were completed. A GSFC review of the results is in progress. The RFP for Phase C/D of the FTS was issued in November 1988, with proposals due in January 1989.

CHANGES FROM FY 1989 BUDGET ESTIMATE

In FY 1989, Congress added $26.0 million to the FTS budget of $20 million to enable an early demonstration flight on the NSTS. The PDR for the DTF-1 is planned to be held in mid-CY 1989. The DTF-1 is planned to be flown in late 1991.

BASIS OF FY 1990 ESTIMATE

In FY 1990 NASA is actively pursuing approaches to encourage the private sector to invest in the FTS. The requested funding will provide for supporting development activities.

Supporting development activities in FY 1990 include crew training, flight operations support, and integrated flight simulations. Studies of OMV interfaces verification will continue. Efforts will continue on applications procedure development, and technology assessment and testing.

BASIS OF FY 1990 FUNDING REQUIREMENT

OPERATIONS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Operations..............................	--	--	--	25,000

OBJECTIVES AND STATUS

Planning for operations and utilization has been an integral part of the SSF design and development program and a major driver in the approaches established for Station assembly, utilization, and evolution. As a long-term permanently manned laboratory in orbit, Freedom will be serving the needs of many disciplines and individuals, and must be designed and operated to be safe, reliable, and accommodating to numerous diverse uses. It must also be cost-effective to operate, economical to utilize and amenable to changes in technology that will be occurring during its planned 30 years in space. The various elements of the development program such as flight systems hardware/software production, operations/utilization capability development, and management and integration will transition, over time, into the components of the operations program. These components include flight and ground hardware and software sustaining engineering, integrated logistics support, user integration and operations support, space system operations support, prelaunch and post-landing operations, and information systems services operations.

BASIS OF FY 1990 ESTIMATE

Although some planning for operations is ongoing within the development program under operations/ utilization capability development, FY 1990 is the first year that funding is required for items that are included in the operations budget of the program. During FY 1990 much of the effort will consist of initial planning for integrated logistics operations and space systems operations. Logistics activities will focus on logistics management and maintenance planning and early planning for initial spares for flight hardware and support equipment. Space systems operations activities will include the study and initiation of the assembly planning tasks.

BASIS OF FY 1990 FUNDING REQUIREMENT

TRANSITION DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Transition Definition..................	4,000	12,000	12,000	25,000

OBJECTIVES AND STATUS

The February 11, 1988, Presidential directive on National Space Policy states that the "Space Station will allow evolution in keeping with the needs of Station users and the long-term goals of the United States." This policy encapsulates the goal of the Transition Definition program and reaffirms the NASA approach to the program since its inception: to design and build a facility that is capable of expanding original capabilities, adding new functional capabilities, and incorporating improved technologies. SSF design reflects consideration of an extended operational lifetime in support of a changing and growing user community.

There are two elements to the Transition Definition program: system studies and analyses; and advanced development. The strategy is to focus these interrelated elements on understanding probable evolution paths and the implications of these on current decisions in the baseline program. Possible evolution paths include: expansion of multi-disciplinary research activities in low Earth orbit, mission to planet Earth, piloted exploration missions, and unmanned planetary missions. The challenge to provide for Station evolution is to keep open options to support whatever future missions may be chosen. Therefore, planning for evolution is by necessity conducted in parallel with the design and development of the baseline Station.

The objectives of the system studies and analysis portion of the program are to concentrate on defining Space Station concepts to support the Human Exploration Missions, the Mission to Planet Earth studies, the continued growth of a multidiscipline Space Station, as well as to identify technology needs. Another important objective is to define and incorporate "scars and hooks" in the baseline program to preserve the capability for evolution.

The specific objectives of the SSF advanced development program are: (1) to enhance baseline Freedom capabilities with an emphasis on increasing productivity and reliability; (2) to reduce operations costs; and (3) to enable Space Station Freedom evolution by providing mature technology in areas required to support advanced missions.

BASIS OF FY 1990 ESTIMATE

The key FY 1990 activities are directly related to the upcoming program PDRs. In the near-term, the Transition Definition program is aimed at defining required "hooks and scars" prior to the start of PDR activities. What remains to be accomplished in FY 1990 is evaluating these design provisions at Level I, 11, and III Change Boards.

During FY 1990, system studies and analysis efforts will build on previous work by narrowing the number of evolution concepts under study. The reference concepts will then undergo feasibility studies at the pre-Phase A level. These studies will include operations analyses to establish the system level implications for the evolution of Station operations and utilization. Special emphasis will be placed on identification of technologies necessary to enable evolution. Thus, a major product of the Transition Definition program is definitized concepts at the system level that will accommodate the mission requirements posed by NASA program offices.

The advanced development program for FY 1990 has two major thrusts: application development and demonstrations, and technology development and evaluation. Tasks under application development and demonstration address the application of knowledge-based system (KBS) technology to on-orbit system control, ground operations support, and the Space Station information systems. The task set for 1989-1990 is aimed at understanding the "hooks and scars" associated with the application of KBS techniques to thermal, electrical power, reaction control, health maintenance, scientific experimentation, data management, command and control, and environmental control and life support systems. Tasks under technology development and evaluation address advanced automation software development, advanced computational hardware and environments, human factors, and robotics systems integration and accommodation. Central to tasks under both thrusts are system engineering issues associated with the integration of KBS applications with conventional automation techniques; requirements for on-board data processing, storage, and communications capacity; software development, testing, and maintenance; and the identification of the boundaries of KBS performance in terms of execution speed and application complexity.

BASIS OF FY 1990 FUNDING REQUIREMENT

ORBITAL DEBRIS RADAR

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Orbital debris radar....................	--	--	--	15,000

OBJECTIVES AND STATUS

This is the first SSF program budget submission for development and construction of an orbital debris radar. Prior to FY 1990, a study effort was being funded by the Office of Space Flight, Advanced Programs Office.

To address the growing national concern over the hazard posed by orbital debris to the space activities of the U.S. requires information of two types: (1) long term monitoring of the small size debris to quantify the trends in debris population, and (2) characterization and assessment of small size orbital debris. Since the SSF is planned to be in orbit for as much as thirty years, it is absolutely vital that the pressurized elements be designed and development to withstand as much of the orbital debris effects as possible. This requires the construction and operation of a radar system that can both quantify and characterize this debris.

The required information for Space Station is the population of one centimeter diameter debris particles (limit of size which can be protected with shielding on the Station). Currently this information is not available from other sources. Preliminary experiments have suggested that the population of this size particles may be higher than expected, but to get definitive information additional measurements with the proper characteristics in a different frequency band are needed.

The radar consists of a ten meter antenna and associated hardware and software to be built under a competitive contract and managed by the Jet Propulsion Laboratory. The exact location of the radar has not yet been determined but ideally it should be as close to the equator as possible in order to cover a wide range of orbits. Once operational, the radar will be able to monitor objects as small as one centimeter in diameter orbiting at five hundred kilometers. It will determine the radar cross-section, altitude (plus or minus five kilometers), and the orbital inclination of the debris.

BASIS OF FY 1990 ESTIMATE

The current schedule for design and construction of the radar consists of a competitive contract award in July 1989, a 21-month design and construction period, and a six month ship, install, and test period. This schedule would make the radar operational in October 1991. The key driver for maintaining this schedule is the design of the SSF pressurized modules. In order to affect this design, information from the radar analysis is needed prior to the critical design reviews, currently scheduled to occur in early 1992. Any delay in the initiation of the radar development will preclude availability of design data in time to influence the critical design efforts. Funding is needed in FY 1990 for the orbital debris radar design and construction work that will lead to obtaining the necessary data in a timely manner.

SPACE
TRANSPORTATION
CAPABILITY
DEVELOPMENT

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT — **SPACE TRANSPORTATION CAPABILITY DEVELOPMENT**

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
	(Thousands of Dollars)				
Spacelab	66.500	80.400	88.600	98.900	RD 2-6
Upper stages	142.200	146.200	138.800	88.600	RD 2-9
Engineering and technical base	133.900	158.900	155.400	189.800	RD 2-11
Payload operations and support equipment	80.900	67.300	64.700	81.100	RD 2-14
Advanced programs	46.400	45.000	52.700	48.700	RD 2-16
Advanced launch systems	65.100	13.000	81.400	5.000	RD 2-19
Tethered satellite system	12.100	23.800	26.400	19.900	RD 2-21
Orbital maneuvering vehicle	46.300	96.500	73.000	107.000	RD 2-22
Total	593.400	631,100	681,000	639,000	

Distribution of Program Amounts By Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center	121.800	146.000	145.400	180.200
Kennedy Space Center	62.500	78.400	78.400	88.800
Marshall Space Flight Center	364.100	329.500	375.000	290.900
Stennis Space Center	9.800	5.600	5.700	5.800
Goddard Space Flight Center	4.200	6.400	7.900	6.400
Jet Propulsion Laboratory	2.100	1.500	4.100	1.200
Langley Research Center	1.100	800	1.400	1.400
Lewis Research Center	1.700	500	2.200	1.800
Ames Research Center	1.200	1.300	--	--
Headquarters	24.900	61.100	60.900	62.500
Total	593,400	631.100	681,000	639.000

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

OFFICE OF SPACE FLIGHT **SPACE TRANSPORTATION PROGRAM**

PROGRAM OBJECTIVES AND JUSTIFICATION

The principal areas of activity in Space Transportation Capability Development include the Spacelab; the Upper Stages required to place satellites in high altitude orbits; the Engineering and Technical Base support at the manned space flight centers; Payload Operations and Support Equipment for accommodating NASA payloads; Advanced Programs study and evaluation efforts; Advanced Launch Systems efforts; the design and development of the United States/Italian Tethered Satellite System; and the development and first flight of the Orbital Maneuvering Vehicle.

Spacelab was developed jointly by NASA and the European Space Agency (ESA). It is a major element of the Space Transportation System (STS) that provides a versatile, reusable laboratory which is flown to and from Earth orbit in the orbiter cargo bay. The development program continues with a recertification program to insure flight safety, the procurement of flight hardware to support the flight program and necessary modifications including replacing the onboard computer system.

Upper Stages are required to deploy payloads to orbits and trajectories not attainable by the Shuttle or core stage expendable launch vehicles alone. The program provides for procurement of stages for NASA missions, for technical monitoring and management activities for government and commercial Upper Stages, and a solid rocket motor integrity program to establish an engineering data base for improving the success rate of U. S. built solid motors.

The Engineering and Technical Base provides the core capability for the engineering, scientific, technical and Safety, Reliability and Quality Assurance (SR&QA) support required at the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the Stennis Space Center (SSC) for research and development activities. Additional requirements above the core level of capability are funded by the benefiting programs.

The Payload Operations and Support Equipment program develops and places into operational status the ground and flight systems necessary to support the NASA STS payloads during prelaunch processing, on-orbit mission operations and, when appropriate, post-landing processing. Included within this program area are the STS optional services for NASA payloads, and multi-mission payload support equipment.

Advanced Programs conducts concept feasibility studies and selected system definitions and preliminary design (Phase B) studies and undertakes related high leverage advanced development to provide the technical and programmatic data to identify evolving space transportation and system requirements and to evaluate new space transportation initiatives. \Complementary objectives are to assimilate generic technology and advanced planning activities, and to provide an advanced planning programmatic link between the Office of Space Flight and other NASA program offices.\ Activity is focused on four major areas--advanced transportation, advanced operations support, satellite servicing and advanced missions. Concept definition and key advanced development are under way and planned in these areas to assess performance, reliability and operational efficiency improvements, and to reduce future program risks and development costs through the effective use of new technology. Included as part of the Advanced Programs Development Program are definition studies of a Assured Crew Return Capability (ACRC) to provide approaches for additional crew return capability from the Space Station manned base.

The Advanced Launch System (ALS), as outlined in the joint DOD/NASA Report to Congress, is a joint DOD/NASA program to develop and field this nation's next generation of unmanned launch system. The ALS program will permit this nation to achieve the goal of reduced cost to space. Both NASA and the DOD are moving aggressively forward with ALS and are jointly managing the effort. Consistent with the ALS agreement, the DOD includes funding for the joint programs in their budget submission. In FY 1988 and FY 1989, the Congressional appropriations transferred to NASA funding for the NASA managed portion of the joint effort. The FY 1990 request for the joint program is included in the DOD budget in anticipation of similar appropriations actions.! NASA has requested separate funds for study efforts for unique civil mission requirements not satisfied in the joint DOD/NASA ALS baseline design.

The Tethered Satellite System (TSS), a joint Italian/United States development effort, will provide a new reusable facility for conducting space experiments and unique tethered applications in regions remote from the Shuttle orbiter. The objectives of the initial TSS mission are twofold: (1) to verify the controlled deployment, operation, and retrieval of the TSS, and (2) to quantify the interaction between the satellite/tether and space plasma in the presence of a electrical current drawn through the tether.

The development of the Orbital Maneuvering Vehicle (OMV), initiated in 1986, will provide a capability for payload delivery, retrieval, and servicing beyond the reach of the Space Shuttle or the Space Station.

OBJECTIVES AND STATUS

Four dedicated Spacelab flights have been flown on the STS including the first Spacelab reimbursable flight, Deutschland-1 (D-1). In addition, several smaller Spacelab elements have flown on other STS flights as partial payloads. These flights have demonstrated the unique capabilities and benefits offered by many of the Spacelab elements. The Spacelab Astro-1 mission, scheduled for the first quarter of CY 1990, will be the verification mission of the Igloo Pallet Configuration of the Spacelab Pallet System (SPS). The Enhanced Multiplexer/Demultiplexer Pallet (EMP) will be verified with the tether satellite system mission. Preparations are now in process for resumption of Spacelab operational flights for DOD, international, and NASA scientific experiments.

In Upper Stages, funding is included for production, launch, flight support, and integration of Inertial Upper Stage (IUS) vehicles to accommodate the TDRS E and F missions, and the Magellan, the Galileo and Ulysses (including a PAM-S vehicle) planetary missions. The IUS was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit.

The Transfer Orbit Stage (TOS) is a three-axis stabilized perigee stage that is being commercially developed by the Orbital Sciences Corporation for use with the Shuttle or on Titan 111. It will have the capability of placing up to 13,000 pounds into geosynchronous transfer orbit. Production, integration and launch operations for a TOS vehicle for the Mars Observer (MO) is included in the FY 1990 budget. MO will be launched on a Titan 111. Funding for a second TOS stage for the Advanced Communications Technology Satellite (ACTS) mission, proposed for termination in the budget, is included through FY 1989 only.

The Solid Propulsion Integrity Program (SPIP) objective is to establish the necessary engineering capability for improving the success rate of U. S. manufactured solid rocket motors. The initial phase of the program, started in 1984, has made excellent progress in determining root causes and solutions to the persistent problems plaguing motor nozzles. The results and findings have been used in the Shuttle Solid Rocket Motor redesign effort. The program scope is being expanded to examine motor bondlines as well as continuing the nozzle efforts.

In Payload Operations and Support Equipment, payload integration support and payload-related hardware are developed and furnished for NASA payloads. Multi-mission payload support equipment is developed and procured including fiber optic cabling and equipment for communication links between the payload processing facilities; standard sets of wire harnesses for interconnection of mixed cargoes in the orbiter payload bay; and payload displays and controls in the orbiter vehicle crew cabin.

In Advanced Programs, concept definition and key advanced development are underway to assess performance, reliability, and operational efficiency improvements, and to reduce future program risks and development costs through the effective use of new technology. Advanced transportation study efforts focus on cargo vehicles, manned vehicles, and space transfer vehicles. Studies are underway to define the evolution of manned vehicles, including Space Shuttle enhancement concepts (Shuttle Block II), and next generation concepts (Shuttle 11). In addition, definition studies are underway to analyze mission requirements for the design and development of an assured crew return capability (ACRC) from the Space Station. Advanced operations support systems efforts focus on the study and assessment of innovative ground, flight and on-orbit operations techniques to achieve improved safety as well as reduced life-cycle costs for space transportation and orbital systems. The complementary Advanced Operation Effectiveness activity will focus on demonstration of autonomous and expert systems technology to improve the safety and reduce the costs of Shuttle operations. The satellite servicing study effort, encompassing satellite servicing systems and tether applications, focuses primarily on the development of systems and procedures designed to utilize Shuttle capabilities that are compatible with the Space Station and the Orbital Maneuvering Vehicle. Advanced missions activity will continue to focus, with expanded scope and increased depth, on potential manned and unmanned missions beyond the Space Station. Focused orbital debris studies, augmented by the development of a debris measurement radar by the Office of Space Station, will be continued.

Studies, with a directed focus building upon the joint DOD/NASA Advanced Launch System (ALS) baseline design, are planned to examine vehicle and propulsion systems to satisfy national requirements. The ALS-Propulsion Focused Technology program, a NASA-managed element of the core DOD/NASA ALS program, is focused on demonstrating the performance and operating capabilities of critical propulsion system components. FY 1990 funding for continuation of this efforts is included in the DOD budget request.

The Tethered Satellite System (TSS) will provide a Shuttle-based facility for electrodynamic and upper atmospheric research. Hardware development was initiated in FY 1984 and systems definition studies were completed in FY 1985. Comprehensive design and requirements validation, procurement of flight hardware elements and tooling, systems development and integration, and deployer manufacturing and integration will continue through 1990. The Italians started satellite and core equipment development in FY 1984. U. S. science instruments for the satellite are being funded in the Space Science and Applications budget. A cooperative first flight for systems validation and electrodynamic research is presently planned for 1991.

The Orbital Maneuvering Vehicle (OMV) is a reusable, remotely operated space tug with the capability to deliver, retrieve and service payloads and spacecraft deployed from the Space Shuttle or Space Station over a wide range of altitudes and inclinations. The development contract was initiated in late 1986 with a planned initial capability in 1991. Based on budgetary reductions and current Shuttle manifest planning, the initial capability requirement has been rescheduled to FY 1994. Uses of the OMV will include supporting scientific experiments and tests and the Space Station as well as satellite servicing and reboost. The FY 1990 budget request includes funds for continuation of the design and development, initial testing, and production of flight hardware.

SPACELAB

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Development	18,700	15,300	18,000	12,000
Operations	47,800	65,100	70,600	86,900
Total	66,500	80,400	88,600	98,900

OBJECTIVES AND STATUS

The Spacelab is a versatile facility designed for installation in the cargo bay of the orbiter which affords scientists the opportunity to conduct scientific experiments in the unique environment of space. The reusable Spacelab system enhances the advancement of scientific research by serving as both an observatory and laboratory in space. Ten European nations, including nine members of the European Space Agency (ESA), have participated in this joint development program with NASA. ESA designed, developed, produced, and delivered the first Spacelab hardware consisting of: a pressurized module and unpressurized pallet segments, an Igloo which is used with pallets to supply equipment, computers and services essential to the experiments, an instrument pointing subsystem (IPS), and much of the ground support equipment and software for both flight and ground operations.

NASA procured an additional set of Spacelab hardware from ESA under terms of the ESA/NASA Memorandum of Understanding and the Intergovernment Agreement. The remaining NASA funded development activities include additional hardware to complete the Spacelab system, ground support equipment, hardware modifications, hardware acquisition, system recertification, and qualification and procurement of reliable and high capacity AP-101SL computers. Support software and procedures development, testing, and training activities not provided by ESA, which are required for the Spacelab, are also included in NASA's funding. Additional Spacelab hardware, including the initial lay-in of spare hardware, is being procured from European and U. S. sources.

NASA has developed two principal versions of the Spacelab Pallet System (SPS): one will support missions requiring the igloo and pallet in a mixed cargo configuration like the Astro series; the other version will support missions that do not require use of the igloo such as the Space Technology Experiment Platform (STEP) and the Tethered Satellite System. Development of the Hitchhiker system is nearly complete. The Marshall Space Flight Center (MSFC) version of the Hitchhiker will fly at the next available opportunity.

The Spacelab operations budget includes mission planning, mission integration, and flight and ground operations. This includes integration of the flight hardware and software, mission independent crew training, system operations support, payload operations control support, payload processing, logistical support and sustaining engineering.

Previous major Spacelab missions include Spacelab-1 flown in FY 1984 and Spacelab-3 and Spacelab-2 which were flown in FY 1985. The first Spacelab reimbursable flight, Deutschland-1 (D-1), was flown during the first quarter of FY 1986. Astro-1, originally planned for flight in FY 1986 for observation of Halley's Comet, was delayed to FY 1990 due to the January 1986 Shuttle accident. The initial flight of the Goddard Space Flight Center Hitchhiker (HG-1) took place in the first quarter of FY 1986.

In addition to these missions, analytical and physical integration, configuration management, and software development for future flights will be conducted. Procurement of spares for both NASA-developed hardware and for hardware developed by U. S. companies under contract with ESA will continue throughout FY 1989 and FY 1990 as will operation of the depot maintenance program for U. S.-provided and European-supplied hardware.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The $8.2 million increase is to support an acceleration of flight opportunities allowed by an increase in the downweight capability of OV-102 and a reduction in DOD flight requirements. Additional flight hardware, direct mission and mission related manpower, and payload operations control center activities are required to support the acceleration of one additional major mission in FY 1990 (SLS-1), in FY 1991 (Atlas 1) and in FY 1992 (Astro-2).

BASIS OF FY 1990 ESTIMATE

The FY 1990 request reflects an increase in the scheduling and frequency of Spacelab missions which had been significantly delayed by the Challenger accident. Funding provides for the integration and payload processing of three to four major and three to four secondary missions per year.

The FY 1990 development funds are required to procure additional computers and experiment hardware to support an accelerated and more active Spacelab traffic flow which otherwise would create hardware shortages. The Spacelab flight hardware recertification, the Hitchhiker programs, and the Enhanced Multiplexer Pallet System (EMPS) are scheduled for completion in FY 1990.

The FY 1990 operations funds are required to support payload operations and to continue payload integration support, mission independent training, and logistics support. This support includes analytical integration, configuration management, hardware integration and software development and integration. Spacelab operations also provides for replenishment spares, the operation of the depots for both U. S. and European hardware and software, and sustaining engineering of all hardware and software. Funding is also included for the Getaway Special (GAS) program which was transferred from Shuttle Operations in FY 1989.

In addition to continuing operations support of the Spacelab mission planned through FY 1991, FY 1990 funding is required to begin mission integration and payload processing support for the U. S. Microgravity Laboratory (USML) mission which is planned for flight in the second quarter of FY 1992.

In addition to NASA missions the Spacelab program will also support three (3) reimbursable missions: the U. S. DOD Starlab, the Japanese SL-J, and the German D-2. Appropriated funding is combined with reimbursable funding to support the total Spacelab operations requirements. In FY 1990, $11.0 million of reimbursable funds are anticipated.

BASIS OF FY 1990 FUNDING REOUIREMENT

UPPER STAGES

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Development	15,500	6,700	4,900	400
Procurement and operations	126,700	139.500	133.900	88.200
Total	142.200	146,200	138.800	88.600

OBJECTIVES AND STATUS

The STS upper stages are required to deploy payloads to orbits not attainable by the Shuttle or core stage expendable launch vehicle alone. The Inertial Upper Stage (IUS), and the commercially developed Payload Assist Modules (PAM-A, PAM-D and PAM-DII) are currently available for use. Several other upper stages are now being commercially developed, including the Transfer Orbit Stage (TOS), which will become available for use in the near future.

The IUS was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit. The IUS has been launched from both the Shuttle and Titan 34-D Expendable Launch Vehicle. Six IUS vehicles are under contract for launch of the Tracking and Data Relay Satellite System (TDRSS) spacecraft. The first three were funded through the TDRSS contract while the others are funded under this budget element. TDRS-D, TDRS-E and -F remain to be launched on the Shuttle. In addition, IUS vehicles will be used for the Magellan, Galileo and Ulysses planetary launches.

A PAM is being procured as a kick stage in conjunction with the IUS for the Ulysses launch. This is the only PAM in the current upper stage budget since the remaining NASA spacecraft that require PAM stages are planned for launch on Delta launch vehicles. The PAM is procured as part of the Delta launch service and therefore is included in the Expendable Launch Vehicle budget.

TOS is a three-axis stabilized perigee stage that is being developed commercially by the Orbital Sciences Corporation for use with the Shuttle and the Titan 111. It will have the capability to place 6,000 to 13,000 pounds into geosynchronous transfer orbit. One TOS/Titan III upper stage is being procured for the Mars Observer mission to be launched in FY 1992; funding of a TOS/Shuttle stage for ACTS is included through FY 1989 only.

The Solid Propulsion Integrity Program was initiated in FY 1984 to establish an urgently needed engineering data base for use of composite materials in upper stage motor nozzles, to minimize risk to planned missions and to restore user confidence in U. S. launch systems. Underlying root causes of persistent problems in motor nozzles have been identified and required data is being generated. Work to examine motor bondlines has been initiated, in addition to increasing the level of effort in motor nozzle studies. The results of this program will continue to be used in support of the Shuttle Solid Rocket Motor.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Funding for Upper Stages is reduced a net of $7.4 million, based on a delay in the funding requirements for the planetary upper stages offset by the requirement to provide FY 1989 funding for a TOS stage for ACTS, to modify the TDRS-F IUS for launch in the STS rather than a Titan, and additional funds for the Solid Propulsion Integrity program.

BASIS OF FY 1990 ESTIMATE

Development and Operations funds in FY 1990 are required to continue progress on the IUS Upper Stages for TDRSS and for the Magellan, Galileo and Ulysses planetary missions and the TOS Upper Stage for Mars Observer. Funding has not been included to continue the TOS stage for ACTS. FY 1990 funds are also necessary to support continuation of the Solid Propulsion Integrity Program

BASIS OF FY 1990 FUNDING R[illegible] EMENT

ENGINEERING AND TECHNICAL BASE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Research and test support................	74,400	94,400	94,900	125,500
Data systems and flight support..........	22,600	23,700	16,900	17,400
Operations support......................	24,100	23,900	32,700	34,300
Launch systems support...................	12.800	16.900	10.900	12.600
Total................................	133.900	158,900	155,400	189.800

OBJECTIVES AND STATUS

The Engineering and Technical Base (ETB) provides the program core capability required to sustain an engineering and development base for various NASA activities at the manned space flight centers. Additional center requirements above the core level are funded by the benefiting programs, such as Space Transportation Operations and Shuttle Production and Capability Development. The centers involved are the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the Stennis Space Center (SSC).

The core level of support varies from center to center due to programmatic and institutional differences. At JSC, the core level requirement is that one shift of operations be maintained in the engineering and development laboratories and the White Sands Test Facility. Safety, reliability and quality assurance (SR&QA) areas are also supported by the ETB core. The core level for the central computer complex is established as a two-shift operation. At KSC, the core level provides for research and development of technology to enhance launch site hardware, ground processing, support services; and SR&QA. ETB funds at MSFC provide for multi-program support activities, including technical labs and facilities, computational and communications services, and at SSC for test facility operations.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The total funding for the ETB has decreased $3.5 million in FY 1989 as the result of reducing laboratory support at JSC and KSC.

BASIS OF FY 1990 ESTIMATE

The requested funding for ETB in FY 1990 not only provides for a continuation of the FY 1989 level of support for required research and development facilities and services at the centers but enables necessary increases in the core for SR&QA requirements, upgrading of engineering labs and engineering support services with state-of-the-art technology and capability to meet critical requirements for technology development, and expanded Class VI computer capabilities at MSFC. FY 1990 funds will also support the first full year of operations of the Class VI computer capability at JSC.

In research and test support, funding is required to support SR&QA activities at JSC, MSFC and KSC. In addition, computational capabilities at MSFC are provided for engineering and science projects through the use of a Class VI computer system. This capability is required for the solution of complex main engine three-dimensional dynamics modeling problems and for complex structural analyses. At JSC, the requested funding will provide for a five-day, one-shift operation for the engineering and development laboratories, such as the Electronic Systems Test Laboratory and the Thermal Test Area, in addition to a Class VI computer system. The computer is required to obtain numerical solutions of very large sector matrices for the aerodynamics, thermodynamics and structural mechanics analysis associated with developing and operating manned and robotic space systems.

Data systems and flight support provides a core level of support based on a five-day, two-shift operation of the central computer complex at JSC. Any additional requirements are the responsibility of the benefiting program.

Operations support funding provides for the maintenance of multi-program research and development facilities and equipment, chemical cleaning, engineering design, technical analysis, component fabrication, and logistics support. Examples of specific services to be provided in FY 1990 include: (1) operation and maintenance of specialized electrical and cryogenic systems; (2) operation of shops to do metal refurbishing, anodizing, plating, stripping, and etching of selected hardware; (3) engineering, installation, operation, and maintenance of closed circuit fixed and mobile television required for the support and surveillance of tests; (4) mission imaging services, including audiovisual mission support; (5) fabrication of models, breadboards, and selected items of flight hardware; and (6) technical documentation services. In addition, FY 1990 funds will provide the basic level of collateral support at SSC for continuing main engine testing activities.

In launch systems support, funding provides for the core capability for the engineering, scientific, and technical support at KSC including technical labs and facilities such as the following labs: (1) launch equipment test lab to develop, test and checkout ground support equipment, structures and pyrotechnics; (2) materials science lab for materials testing and malfunction analysis; (3) robotics labs for developing robotic applications for payload preparation and the launch environment; (4) digital electronics lab for testing and evaluating devices and circuits, controls and displays and computer networks. In addition, funding supports several other labs critical to launch support including the instrumentation and hazardous gas lab, fiberoptics/communication lab, software development lab, atmospheric lab, expert systems lab, and the biomedical lab.

BASIS OF FY 1990 FUNDING REOUIREMENT

PAYLOAD OPERATIONS AND SUPPORT EOUIPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Payload operations......................	66,100	53,300	49,700	60,400
Payload support equipment................	14.800	14.000	15.000	20.700
Total................................	80.900	67,300	64.700	81.100

OBJECTIVES AND STATUS

The objectives of the Payload Operations and Support Equipment program are to provide payload services, which are required beyond the basic STS standard services for all NASA missions and to provide multi-mission support equipment in support of payload operations. Payload operations provide unique hardware, analyses, and launch site support services to NASA missions. The payload support equipment budget funds the development and acquisition of multi-mission reusable ground support equipment required for a wide range of payloads. This includes test equipment required to checkout payload-to-orbiter interfaces at KSC, mixed cargo hardware such as standard cable harnesses, and displays and controls related to payload bay operations.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Payload Operations requirements have decreased a net of $2.6 million reflecting reductions enabled by deferring the replacement of the Super Guppy engines and by transferring ongoing advance development activities for satellite servicing and flight demonstrations to Advanced Programs. The decrease is partially offset by an increases to support Hubble Space Telescope launch-on-need planning, and development of the remotely-operated electrical umbilical and the mid-deck accommodation rack.

BASIS OF FY 1990 ESTIMATE

Payload operations funding is required to furnish continued payload services for currently scheduled NASA launches. Major NASA payloads receiving support during this year include Hubble Space Telescope (HST), Tracking and Data Relay Satellite (TDRS), Galileo, Ulysses, Space Radar Laboratory (SRL), Space Life Sciences Laboratory (SLS), Upper Atmospheric Research Satellite (UARS), Commercially Developed Space Facility (CDSF), and Gamma Ray Observatory (GRO) Provision also has been made to replace outdated engines on the Super Guppy. In addition, funding is required to initiate technical integration and operations activities to assure compatibility between Shuttle capabilities and Space Station transportation requirements. Initial efforts are included to support development of a standard docking module for the orbiter which would be used by the Space Station and other on-orbit docking requirements. Private sector investment is being pursued for this development.

Payload support equipment estimates reflect the requirement to modify and upgrade selected payload integration facilities for safer, more efficient operations. FY 1990 funding for multi-mission payload support equipment is required for the development, testing and delivery of payload common communication equipment (PCCE) to accommodate required payload data transmission, and initial spares provisioning for Cargo Integration Test Equipment (CITE) and PCCE. Funds for fiber optic cabling and an upgraded operational intercom system in the industrial area at KSC are included in this budget to provide increased reliability and quality of data transmission among cargo facilities. Multi-mission payload support equipment funding also includes orbiter/payload interface hardware for groups of payloads, cargo bay cabling, modified aft flight deck panels, and associated display and controls.

BASIS OF FY 1990 FUNDING REQUIREMENT

ADVANCED PROGRAMS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Advanced programs........................	46,400	45,000	52,700	48,700

OBJECTIVES AND STATUS

The principal objectives of Advanced Program Development are to conduct concept definitions, selected system definition and preliminary design studies, and key advanced developments addressing civil requirements for increased reliability, cost effectiveness, and capability in space flight systems. Information from these studies will support decisions on the best alternatives for developing capabilities required to support future civil mission options. High-leverage advanced development efforts will be conducted to reduce future program development risks and costs through the effective application of new technology. A complementary objective is to provide an advanced planning programmatic link between the Office of Space Flight and other NASA program offices.

The Advanced Program Development effort is focused on four major areas--advanced transportation, advanced operations support, satellite servicing, and advanced missions. Advanced transportation activities include concept definition of manned launch vehicles and upper stages and systems definition of crew return and cargo vehicles. For manned flight, parallel and complementary studies continue to support Shuttle evolution and to develop the requirements and concepts for a next generation manned vehicle. NASA and DOD continue closely related and coordinated cargo vehicle studies (Shuttle-C and the Advanced Launch System) to define unmanned heavy lift launch vehicles to satisfy both near and long-term mission requirements. \The Phase-B preliminary design phase for an assured crew return capability (ACRC) will be initiated in support of the Space Station Freedom.) Studies in the upper stages area will include assessment of possible upgrades to the existing Centaur and concept definition of a new, high-performance cryogenic Space Transfer Vehicle to meet advanced missions requirements.

Efforts in advanced operations support systems continue to address advanced operations effectiveness as the key parameter in reducing life-cycle costs for space transportation and orbital systems as well as improving reliability and safety, Innovative operations techniques and approaches are under study and being assessed for improvement of both ground and flight support systems. Advanced development emphasizes demonstration of expert and autonomous systems technologies for current and future space transportation vehicles.

The satellite servicing program focuses primarily on the definition of systems and procedures designed to enhance on-orbit servicing which utilize Shuttle and the planned Orbital Maneuvering Vehicle (OMV) and are planned to be compatible with the Space Station. Studies are under way to define the servicing activities associated with rendezvous and proximity operations from the Shuttle and remote servicing using the OMV. The definition of tankers, couplings, telerobotic servicing aids, techniques and procedures to support on-orbit servicing is also continuing in FY 1989. Transportation-related tether application studies are continuing to define and implement flight experiments and demonstrations including orbital altitude changes without the use of propellants, tether initiated recovery systems for returning small payloads and articles from space, and innovative transportation systems concepts for automated and manned exploration missions in and beyond Earth orbit.

Advanced mission efforts will continue to focus on potential manned and unmanned missions beyond the Space Station. A major effort to define the orbital debris environment continues in FY 1989 along with studies to investigate ways to minimize debris accumulation and to develop techniques for protection/avoidance procedures for future space orbital systems. The development of the orbital debris radar will be provided under the Space Station program, to begin in FY 1990.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Advanced Program Development funding increased by $7.7 million due to the transfer of satellite servicing activities formerly funded under Payload Operations and Support Equipment. The transfer resulted from an administrative decision to consolidate satellite servicing funding and to improve management control and accountability.

BASIS FOR FY 1990 ESTIMATE

In FY 1990, major emphasis will continue to be placed on concept definition, system definition, and advanced development for advanced transportation, advanced operations, satellite servicing and advanced missions. In the advanced transportation area, studies to define the evolution of manned vehicles, including Space Shuttle improvement and concepts for the next generation manned launch system will be continued. Funding of the ACRC Phase B definition effort will be continued in FY 1990. Definition of the Space Transfer Vehicle will also continue as well as selected advanced development activities in cryogenic storage and transfer, avionics and propulsion.

Advanced operations efforts will emphasize the identification and demonstration of technologies to improve efficiency, flexibility and reliability of current and future space transportation systems. Included in advanced operations is the selective application of expert systems, robotics, automation, and other technologies to labor-intensive and hazardous operations. Launch processing systems, mission control applications, flight planning, training, simulation and other environments will be targeted to demonstrate emerging technologies for improve ground and flight operations.

The satellite servicing area will explore effective manned and unmanned remote servicing concepts. Systems, tools, and techniques will be defined to refuel, repair, and retrieve satellites on a routine basis. Detailed engineering studies will continue to determine the efficiency of future tethered platform applications. Orbital debris studies will also continue to define performance drivers for radar development and operations and to better understand and model the orbital debris environment.

Advanced missions beyond the Space Station will be studied with expanded scope and increased depth. Studies will be conducted to identify potential demands on transportation systems to support agency new initiative planning for human exploration missions (Lunar/Mars).

BASIS FOR FY 1990 FUNDING REQUIREMENT

ADVANCED LAUNCH SYSTEM (ALS)

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Advanced launch systems (civil)..........		13,000	6,500	5,000
Advanced launch systems (propulsion).....	65.100		74.900	
Total................................	65.100	13.000	81.400	5.000

OBJECTIVES AND STATUS

The objective of the joint DOD/NASA Advanced Launch System (ALS) program is to define a new heavy lift launch capability based on advanced technology which will reduce the cost of placing payloads in space. As specified in the ALS management plan, the ALS propulsion advanced development program is led by NASA. Initiated in FY 1987, the ALS propulsion advanced development (formerly the ALS propulsion focused technology) program focuses on demonstrating the performance and operational capabilities of critical propulsion system components prior to committing to a final design for the flight hardware design and development program. This is an integral element in the joint program which is included in the DOD budget request. In addition, NASA has the funding responsibility to satisfy unique civil requirements not addressed by the joint ALS baseline design. The ALS/Civil studies, initiated in FY 1989, are to refine the definition of civil mission requirements for the ALS program, define civil program requirements for utilization of the ALS, and establish synergism between ALS and civil transportation elements.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease in FY 1989 for unique civil requirements reflects the reduced scope of planned studies consistent with the deferral of ALS full-scale development activities. The DOD includes total funding for the joint program activities in their budget request. The increase in propulsion advanced development activities reflects the applicable portion of an appropriation transfer from DOD as directed by Congress.

BASIS FOR FY 1990 ESTIMATE

The joint DOD/NASA ALS program is in the Phase II systems definition stage. Complementary efforts by NASA and DOD are underway to coordinate the ALS Advanced Development activities to most effectively utilize the expertise and facilities of both agencies. These propulsion activities address components and subsystems including combustors, gas generators, turbopumps, control systems components and instrumentation, and health monitoring system components and diagnostic sensors for liquid oxygen/hydrocarbon and liquid oxygen/liquid hydrogen engine systems. Some activity is also being devoted to mid-size solid rocket motor components and combustion technology to support one unique ALS vehicle concept. Consistent with the basic agreement, funding for the NASA activity to meet the joint requirements of this program is included in the DOD budget request.

The ALS/Civil studies will continue with emphasis on the accommodation of advanced missions for human and robotic exploration of the solar system. Inherent in the'se studies is a series of trades to determine the most effective means of providing services to nonstandard spacecraft and payloads. The focus of the studies includes a transportation infrastructure study, payload interface definition, upper stages study, examination of potential booster commonality, and requirements for vehicle man-rating.

BASIS OF FY 1990 FUNDING REOUIREMENT

TETHERED SATELLITE SYSTEM

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Tethered satellite system................	12,100	23,800	26,400	19,900

OBJECTIVES AND STATUS

The development of a Tethered Satellite System (TSS) will provide a new reusable facility for conducting space experiments at distances up to 100 kilometers from the Shuttle orbiter while being held in a fixed position relative to the orbiter. A number of significant scientific and engineering objectives can be uniquely undertaken with a TSS facility such as the observation of important atmospheric processes occurring within the lower thermosphere, new observations of crustal geomagnetic phenomena, and entirely new electrodynamic experiments interacting with the space plasma. This is being undertaken as a cooperative development program with the Italian government. Formal signing by representatives of both governments of a Memorandum of Understanding took place in March 1984.

The United States is responsible for overall program management, overall systems engineering and integration, orbiter integration, ground and flight operations, development of the deployment mechanism and provision of the non-European instruments (OSSA Funded). The U. S. effort was initiated in 1984. The Italians are responsible for the design and development of the satellite and the European instruments being flown on the joint missions. They initiated their development efforts in 1984.

CHANGES FROM FY 1989 BUDGET ESTIMATES

The $2.6 million increase will support necessary design changes to the mechanisms used to provide control during deployment and retrieval and increase systems integration effort.

BASIS OF FY 1990 ESTIMATE

The FY 1990 funding supports continuation of TSS Development activities consistent with the planned engineering verification flight (TSS-1) in early FY 1991. Current plans call for completion of U. S. hardware assembly in FY 1989 followed by deployer qualification. Integration of the Italian-provided satellite and the deployer-mounted science instruments is now planned to start at KSC in mid-FY 1990, in time to prepare the TSS-1 for flight.

BASIS OF FY 1990 FUNDING REOUIREMENT

ORBITAL MANEUVERING VEHICLE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Orbital maneuvering vehicle.............	46,300	96,500	73,000	107,000

OBJECTIVES AND STATUS

The reusable Orbital Maneuvering Vehicle (OMV) will provide a new STS capability for conducting orbital operations with spacecraft and payloads beyond the practical operational accessibility limits of the baseline STS. By means of direct man-in-the-loop control, the OMV is being designed to operate as far as 1200 nautical miles altitude above the orbiter. The OMV will provide delivery, maneuvering, and retrieval of satellite payloads to and from altitudes or inclinations beyond the existing STS capability; reboost of satellites to original operational altitudes or higher; delivery of multiple payloads to different orbital altitudes and inclinations in a single flight; and safe deorbit of satellites which have completed their useful life, The OMV is being designed with a limited space-basing capability with the intent of eventually being able to serve the Space Station and to accommodate add-on future "mission kits" needed to support more advanced missions such as the servicing of satellites and platforms and the retrieval of space debris representing an orbital hazard to all future space missions. TRW was competitively selected and is now under contract to develop the OMV. The preliminary design review was held in 1988.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The $23.5 million decrease from the FY 1989 revised budget estimate reflects a decision to delay the planned first flight of the OMV from FY 1993 to FY 1994 in order to provide an opportunity to reassess the preliminary design in light of currently projected user requirements including the Space Station.

BASIS FOR FY 1990 ESTIMATE

The funds provided in FY 1990 will be used to continue OMV hardware design and development and to finalize OMV specifications required for the critical design review. Critical design review and commencement of hardware fabrication is scheduled for 1990. The flight readiness date for the OMV is FY 1994.

SPACE SCIENCE
AND APPLICATIONS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1990 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR SPACE SCIENCE AND APPLICATIONS

	Budget Plan				
		1989		1990	
Programs	1988 Actual	Budget Estimate	Current Estimate	Budget Estimate	Page Number
		(Thousands of Dollars)			
Physics and astronomy	614,400	791,600	734,100	894,500	RD 3-1
Life sciences	72,200	101,700	78,100	124,200	RD 4-1
Planetary exploration	327,700	404,000	416,600	396,900	RD 5-1
Earth Science	389,200	450,400	413,700	434,300	RD 6-1
Materials processing in space	62,700	73,400	75,600	92,700	RD 7-1
Communications	94,800	16,200	92,200	18,600	RD 8-1
Information systems	20.800	22.300	19.900	34.100	RD 9-1
Total	1.581.800	1,859,600	1.830.200	1,995,300	

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

PHYSICS AND ASTRONOMY PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Hubble space telescope development.......	93,100	102,200	95,900	67,000	RD 3-7
Gamma ray observatory development........	53,400	41,900	41,900	26,700	RD 3-9
Global geospace science..................	18,600	101,400	64,400	112,300	RD 3-11
Advanced x-ray astrophysics facility development (AXAF)....................	--	27,000	16,000	44,000	RD 3-13
Payload and instrument development.......	46,600	77,100	81,700	71,400	RD 3-15
Shuttle/Spacelab payload mission management and integration.............	47,800	61,500	69,700	86,100	RD 3-17
Space station integrated planning and attached payloads.....................	18,900	8,000	8,000	23,000	RD 3-19
Explorer development....................	67,900	82,100	82,100	93,200	RD 3-20
Mission operation and data analysis......	140,500	156,200	143,200	204,800	RD 3-23
Research and analysis...................	82,900	89,100	85,800	112,500	RD 3-26
Suborbital program......................	44,700	45,100	45,400	53,500	RD 3-28
Total.............................	614,400	791,600	734,100	894,500	

Distribution of Program Amount by Installation

Johnson Space Center	13.448	12.677	12.983	16.917
Kennedy Space Center	7.880	8.087	8.036	11.647
Marshall Space Flight Center	257.020	307.696	202.328	189.002
Goddard Space Flight Center	243.352	343.411	401.717	543.084
Jet Propulsion Laboratory	19.764	15.005	18.381	17.988
Ames Research Center	13.746	15.542	15.936	25.886
Langley Research Center	65	150	--	--
Lewis Research Center	56	--	50	500
Headquarters	59.069	89.032	74.669	89.476
Total	614.400	791.600	734.100	894.500

OBJECTIVES AND JUSTIFICATION

The objectives of the Physics and Astronomy program are to increase our understanding of the origin and evolution of the universe, the fundamental laws of physics, and the formation of stars and planets. Objects studied by the Astrophysics program include distant galaxies and galactic clusters, as well as stars and other structures in nearby galaxies and the interstellar medium in our galaxy. Unusual and exotic phenomena--such as quasars, neutron stars, pulsars and black holes--are of particular interest to the Astrophysics program, and are the target of many ground-based and space-based research programs.

In the Space Physics program, intensive study of our own Sun, with its multitude of time-varying phenomena, provides key answers to a vast range of questions requiring comprehensive research into solar-terrestrial processes and the physics and coupling between the solar wind, magnetosphere, ionosphere, and atmosphere.

The objectives of the Physics and Astronomy program are accomplished with a mixture of large, complex free-flying space missions, less complex Explorer spacecraft, Shuttle/Spacelab flights and suborbital opportunities. In the future, the Space Station will act as a platform for attached payloads and potentially as a servicing point for major free-flying observatories which require assembly, maintenance and refurbishment in orbit. Space-based research allows observations in wavelength regions such as the infrared or the ultraviolet which cannot be carried out on the ground due to the obscuring effects of the atmosphere. Also, observations in the visible light region are vastly improved when conducted above the atmosphere. The entire program rests on a solid basis of supporting research and technology, data analysis, and theory.

Research teams involved in this program are located at universities, industrial laboratories, NASA field centers, and other government laboratories. The scientific information obtained and the technology developed in this program are made available to the scientific communities and the general public for application to the advancement of scientific knowledge, education and technology. The Physics and Astronomy missions undertaken to date have been extraordinarily successful. These include the High Energy Astronomical Observatories (HEAO, 1977-1979), International Ultraviolet Explorer (IUE, 1978), Solar Maximum Mission (SMM, 1980), Active Magnetospheric Particle Trace Explorer (AMPTE, 1984), Dynamics

Explorer (DE, 1981), Interplanetary Monitoring Platform (IMP-8, 1972), International Sun-Earth Explorers (ISEE 1 & 2 and ICE, 1977-78), Infrared Astronomy Satellite (IRAS, 1983) and San Marco-D (1988). The IUE, SMM, AMPTE, IMP, DE and ICE are still operating, and new scientific results are continually emerging from these, as well as from the high quality data sets archived from the HEAO's, ISEE 1 & 2 and IRAS missions.

The Hubble Space Telescope, scheduled to be launched by the Space Shuttle during FY 1990, will provide an international spaceborne astronomical observatory capable of measuring objects appreciably fainter and more distant than those accessible from the ground, since it will be above the turbulent and absorbent atmosphere. This telescope will be able to resolve spatial features by a factor of ten better than ground-based optical telescopes, and will observe the universe at approximately seven times the distances now possible. This means approximately 350 times the volume of the present universe will be available for study. This increased capability will allow us to address basic questions concerning the origin, evolution, and disposition of galaxies, quasars, clusters, and stars, thus allowing us to significantly increase our understanding of both the early and present universe--its beginning and end.

The Gamma Ray Observatory (GRO) mission will be launched by the Space Shuttle in FY 1990. This mission will measure gamma rays, which are produced by the most energetic and exotic fundamental physical processes occurring in nature. Instruments on this mission will provide unique information on phenomena occurring in quasars, active galaxies, black holes, neutron stars, supernova, and the nature of the mysterious cosmic gamma-ray bursts.

The Global Geospace Science (GGS) program was approved as an FY 1988 new start. It is a complementary science mission to the Collaborative Solar-Terrestrial Research (COSTR) program and enables the U.S. to move from a supporting to a leadership role in solar-terrestrial physics. These projects, collectively referred to as the International Solar-Terrestrial Physics (ISTP) program, are being conducted in cooperation with the European Space Agency (ESA) and the Japanese Institute of Space and Aeronautical Science (ISAS). GGS will make the first coordinated geospace measurements in key plasma source and storage regions, with emphasis on the cause-effect relations of energy flow. Together with COSTR, GGS represents research of the highest scientific merit.

The Advanced X-ray Astrophysics Facility (AXAF) was approved as an FY 1989 new start for the x-ray telescope assembly and high resolution mirror assembly. The start of instrument development is planned for FY 1990, with spacecraft development expected in FY 1992. AXAF will be a major national observatory for x-ray astronomy. The 1.2m class grazing incidence telescope will provide a factor of 100 increase in sensitivity, a factor of 10 increase in angular resolution and double the energy coverage which was provided by the Einstein observatory (HMO-2). It will provide new observations and insights in studies of stellar structure and evolution, large-scale galactic phenomena, active galaxies, clusters of galaxies and cosmology. It will restore U.S. leadership in a field pioneered by U.S. astronomers.

Advanced Technological Development activities will continue on the Orbiting Solar Laboratory (OSL), a platform for studies of solar magnetic structures, processes and surface atmosphere, toward a potential new start in the early 1990's. Definition studies of the advanced technology necessary for the Space Infrared Telescope Facility (SIRTF) will continue. SIRTF is intended to measure phenomena associated with the beginning of an evolutionary cycle. This includes cosmic dust, cool interstellar material, star formation, and proto-planetary nebulae in both our galaxy and others.

Since the inception of the U.S. space program, the Explorer program has been the means for fast-turnaround scientific space missions. The Physics and Astronomy Explorers have been extremely successful. The IUE, a U.S./ESA endeavor, has recently shown that our galaxy has a halo of gas with a temperature of over a million degrees, while the **IRAS**, a joint U.S./U.K./Netherlands project, has detected and cataloged over 300,000 infrared sources and has shown star formation in other galaxies to be more prevalent than previously thought. IRAS has also demonstrated that at least one quasar has its dominant energy release in the infrared spectral region. Since IRAS completed operations in late 1983, these discoveries have come from analysis of archival data, with many more such results expected. ICE, which was designed to provide solar wind data, was redirected in 1985 for the first successful encounter with a comet when it passed through the tail of Comet Giacobini-Zinner, and made Halley's Comet observations in 1986. San Marco-D, a joint NASA/Italian spacecraft, was launched in March 1988. After successfully taking equatorial measurements of the ionosphere, the spacecraft reentered the Earth's atmosphere in December 1988.

Two major Explorer missions are now under development: the Cosmic Background Explorer (COBE) is planned for launch in FY 1989, and the Extreme Ultraviolet Explorer (EWE) which is scheduled for launch in FY 1992. A third mission, the X-ray Timing Explorer (XTE), is under definition. In addition, a U.S. instrument has been developed for inclusion on the Roentgen Satellite (ROSAT), being built by the Federal Republic of Germany and scheduled for launch in FY 1990. A Cosmic Ray Isotope Experiment (CRIE) has been developed along with a DOD experiment for flight aboard the Combined Release and Radiation Effects Satellite (CRRES), a collaborative mission with DOD and is also scheduled for launch in FY 1990. We are developing an instrument for flight on the Japanese Solar-A mission (previously called the High Energy Solar Physics Mission, HESP). Solar-A will be launched in FY 1991 to study the Sun during the upcoming solar maximum. Finally, the Explorer program supports U.S. participation in the Japanese Astro-D Spectroscopic X-ray Observatory mission, to be launched in FY 1993.

The Astrophysics program continues its involvement in the Shuttle/Spacelab program with Astro-1, a set of ultraviolet and soft x-ray telescopes and spectrometers, scheduled for a launch in FY 1990. Astro-1 will investigate the interstellar medium by following up on discoveries made with the IUE. Mission management activities will continue with increasing emphasis on major life sciences and microgravity research missions such as the Spacelab-Life Sciences (SLS), the International Microgravity Laboratory (IML) series and the United States Microgravity Laboratory (USML) series.

Payload and instrument development activities provide the data necessary to conduct basic research projects and to provide correlative and developmental feasibility information for major free-flying spacecraft. Instrument development activities include Shuttle payloads such as the Tether Satellite System (TSS). Also included are Space Plasma Physics flight of opportunity instruments such as those for the Japanese Geotail spacecraft and the European Solar Heliospheric Observer (SOHO) and Cluster spacecraft. This Collaborative Solar Terrestrial Research (COSTR) instrumentation provides the U.S. complement for the European Solar Terrestrial Science Programme (STSP).

The first nearby Supernova since the invention of the telescope appeared in the southern skies in 1987. Since that time, the Physics and Astronomy program has conducted a broad campaign of observations using the Deep Space Network, aircraft, balloons, rockets, and existing spacecraft to take advantage of this unique scientific opportunity.

During the Shuttle recovery period, suborbital observation from balloons, sounding rockets, and high-altitude aircraft have taken on increased significance. This enhanced effort will provide observations and instrument development opportunities for various research groups. Furthermore, increased emphasis will also continue in the Research and Analysis (R&A) and the Mission Operations and Data Analysis (MO&DA) areas in order to maintain a vital research base in Physics and Astronomy.

BASIS OF FY 1990 FUNDING REQUIREMENT

HUBBLE SPACE TELESCOPE DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Spacecraft	80,000	90,300	84,900	59,000
Experiments	13.100	11.900	11.000	8.000
Total	93.100	102.200	95,900	67.000
Mission operations and data analysis	(99,200)	(113,300)	(98,300)	(134,400)
Space transportation system operations	(31,200)	(51,600)	(85,500)	(--)

OBJECTIVES AND STATUS

The Hubble Space Telescope (HST) will make a major contribution to understanding the stars and galaxies, the nature and behavior of the gas and dust between them, and the broad question of the origin and scale of the universe. The HST will operate in space above the atmospheric veil surrounding the Earth, increasing dramatically the volume of space accessible for observations. With its significant improvements in resolution and precision in light sensitivity and in wavelength coverage, the HST will permit scientists to conduct investigations that could never be carried out with ground-based observatories limited by the obscuring and distorting effects of the Earth's atmosphere.

The HST will enhance the ability of astronomers to study radiation in the visible and ultraviolet regions of the spectrum. It will be more sensitive than ground-based telescopes and will allow the objects under study to be recorded in greater detail. It will make possible unique observations of objects so remote that the light will have taken many billions of years to reach the Earth. As a result, we will be able to look farther into the distant past of our universe than ever before. The HST will also contribute significantly to the study of the early state of stars and the formation of solar systems, as well as the observation of such highly-evolved objects as supernova remnants and white dwarf stars. With the HST, we may be able to determine the nature of quasars and the processes by which they emit such enormous amounts of energy; it may also be possible to determine whether some nearby stars have planetary systems.

The HST is scheduled to be delivered into orbit by the Space Shuttle in December 1989. Data from its scientific instruments will be transmitted to Earth via the Tracking and Data Relay Satellite System. The HST is designed for on-orbit maintenance and repair.

During FY 1988, the HST program continued at a reduced level of activity. The schedule for launch and operations was adjusted as a result of changes to the STS manifest. HST program activity focused on corrections to a few cases of off-nominal systems performance observed in the intensive period of testing in late FY 1986. This included rework of some components and instruments, improvements to the power system, and adjustments to the thermal control system. In addition to this work on the HST spacecraft, the planned tests of the ground system continued, building toward final operational capability on the stretched-out launch schedule. Work also continued on preparing for the future on-orbit servicing of HST spacecraft. A logistics system was put in place, and development was underway on advanced scientific instruments and other components for orbital replacement. Astronauts conducted realistic training with the replacement components, using specially-developed tools.

Planning for FY 1989 reflects the added delays in the STS launch schedule. After a pre-ship functional test verifies the readiness of the HST spacecraft for shipment, it will enter a period of inactive storage. Assuming a successful flight test of the modified C5-A transport plane, the spacecraft will be flown to Kennedy Space Center in the summer 1989 for final launch preparations. Ground system verification and buildup to full operational capability will continue, consistent with the extended launch schedule.

CHANGES FROM FY 1989 BUDGET ESTIMATE

In light of the launch rescheduling, development funding was reduced'in order to provide funds to the Galileo program to ensure its 1989 launch readiness, as well as to initiate the Mars Balloon Relay experiment equipment accommodation aboard the Mars Observer spacecraft.

BASIS OF FY 1990 ESTIMATE

The FY 1990 funding level is required to complete those program activities that were delayed because of adjustments to the STS launch schedule. These activities include pre-ship preparation of the spacecraft, shipment to the Kennedy Space Center, launch preparations and launch operations at Kennedy, and the initial phases of orbital operations. In addition, the requested funding level will support the buildup of the HST ground system to the level required for sustained science operations.

BASIS OF FY 1990 FUNDING REOUIREMENT

GAMMA RAY OBSERVATORY DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Spacecraft..............................	41,800	29,900	32,300	21,500
Experiments and ground operations........	11,600	12,000	9,600	5,200
Total................................	53,400	41,900	41,900	26,700
Mission operations and data analysis.....	(--)	(1,000)	(1,000)	(11,000)
Space transportation system operations..,	(12,500)	(51,600)	(52,600)	(55,500)

OBJECTIVES AND STATUS

The Gamma Ray Observatory (GRO) will study the highest energy electromagnetic radiation emitted from sources in the cosmos. This spectral region represents one of the last frontiers in astronomy to be studied at high sensitivity. Because of their extreme energy, gamma-rays are produced by the most energetic and intriguing phenomena occurring in the universe: phenomena occurring in the central energy source region of quasars, in supernovae, near black holes, and on the surface of neutron stars. Gamma-rays provide the unique direct signature of all nuclear processes which occur in astrophysics: the synthesis of elements, cosmic rays interacting in the interstellar medium, and transformations involving the fundamental particles of physics. GRO will provide new information on phenomena ranging from the enigmatic, and yet unidentified, cosmic gamma-ray bursts, to the diffuse gamma-ray sky background, whose origin must have cosmological significance.

The GRO science and instrumentation rests on a foundation of exploratory investigations and developments from previous spacecraft, such as the Small Astronomy Satellite-2 (SAS-2, 1972), the High Energy Astronomical Observatories (HEAO's 1 and 3, 1977 and 1979), and the European COS-B (1975). A community of astronomers and physicists has built up both the data analysis experience and developed the theoretical concepts to complete the infrastructure required for a successful space mission. Participation in the GRO mission includes the university science community as well as government and industry. International involvement, with a complete Principal Investigator team based in Europe, is extensive.

Due to the low flux of cosmic gamma-rays, their penetrating nature, and the high background produced by cosmic-ray interactions, detailed observations require large instruments to be flown in space for extended periods of time. The four complementary instruments selected for GRO represent a quantum jump in sensitivity, spectral range, and spectral, spatial, and temporal resolution over any previous missions or instruments in these energy ranges. GRO, scheduled for launch on the Space Shuttle in **1990,** is designed to be pointed at fixed directions in space for hours or weeks to obtain the long exposures required.

In **FY 1988,** the modal survey and static structural loads tests were completed and all spacecraft subsystems for GRO were delivered. In **FY 1989,** all instruments will be delivered to TRW and integrated with the GRO spacecraft which will then undergo functional and environmental observatory testing.

BASIS OF FY 1990 ESTIMATE

FY 1990 funding is required to ship the spacecraft from TRW to Kennedy Space Center, to support launch preparations, to launch GRO in April 1990, and to support post-launch checkout.

BASIS OF FY 1990 FUNDING REQUIREMENT

GLOBAL GEOSPACE SCIENCE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Global geospace science..................	18,600	101,400	64,400	112,300
STS operations..........................	(--)	(13,000)	(5,300)	(10,100)

OBJECTIVES AND STATUS

Global Geospace Science (GGS) will be part of the United States' contribution to the International Solar Terrestrial Physics (ISTP) program. This program is an international, multi-spacecraft, collaborative science mission designed to provide the measurements necessary for a new and comprehensive understanding of the interaction between the Sun and the Earth.

GGS is a complementary science mission to the Collaborative Solar Terrestrial Research (COSTR) program which provides instruments and launch support to gain science return in a cooperative effort with the European Space Agency (ESA) and the Japanese Institute of Space and Aeronautical Science (ISAS). The scientific value of this effort will be greatly enhanced by the addition of the two GGS spacecraft. The combined program will include five spacecraft missions: two U.S. spacecraft, Wind and Polar; two ESA spacecraft, SOHO and Cluster; and one ISAS spacecraft, Geotail.

The GGS mission will measure and model the effects of the Sun on the Earth's space system to enhance our understanding of the processes and flow of energy and matter in the solar energy chain from outer geospace to atmospheric deposition. GGS will also enhance our ability to assess the importance of variations in atmospheric energy deposition from the geospace system to the terrestrial environment. GGS consists of two fully-instrumented U.S. spacecraft, Wind and Polar, making simultaneous measurements in key geospace regions. Instruments and theory investigations were selected through an Announcement of Opportunity to U.S. and foreign investigators. GGS provides the first coordinated geospace measurements in key plasma source and storage regions, multi-spectral global auroral imaging, and multi-point study of magnetospheric response to solar wind. Wind and Polar are planned for launch in FY 1993.

Essentially all commitments by foreign governments are in place and development activities have commenced. Spacecraft contract award is planned for the second quarter of FY 1989, as is final confirmation and initiation of instrument development activity. GGS allows the United States to serve as a full partner in the ISTP program, reinforcing our commitments to international cooperation and maintaining a leadership role in solar-terrestrial physics.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Funding has been reduced by $35.0 million consistent with specific Congressional direction. $2.0 million was also reallocated to other high-priority Physics and Astronomy programs.

BASIS OF FY 1990 ESTIMATE

Definition studies are complete and FY 1990 funds are required to continue development of the GGS spacecraft, instruments and ground system. FY 1990 funding will allow continuation of these early development efforts in order to take advantage of simultaneous measurements provided by the COSTR program and other solar-terrestrial research efforts.

BASIS OF FY 1990 FUNDING REOUIREMENT

ADVANCED X-RAY ASTROPHYSICS FACILITY DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Mirror development......................	--	23,000	16,000	35,000
Experiments............................	--	4.000	--	9,000
Total................................	--	27.000	16.000	44.000
Mission operations and data analysis.....	(--)	(--)	(--)	(1,000)

OBJECTIVES AND STATUS

The Advanced X-ray Astrophysics Facility (AXAF) is the next major initiative in x-ray astronomy and is the third of the four Great Observatories. AXAF will provide new observations and insights in studies of stellar structures and evolution, large-scale galactic phenomena, active galaxies, clusters of galaxies, and cosmology. The 1.2 meter grazing incidence telescope will provide a factor of 100 increase in sensitivity, a factor of ten increase in angular resolution, double the energy coverage which was provided by the Einstein Observatory (HEAO-2), and will address fundamental questions of modern astrophysics. Timely development of the AXAF program is required in order to fly in concert with the Hubble Space Telescope, which will observe the universe in visible and ultraviolet radiation, and the Gamma Ray Observatory, which will conduct observations in the gamma ray spectrum. The scientific return of these "Great Observatories" will be enhanced enormously if flown together to observe the whole range of phenomena in the cosmos, from the most tranquil to the most violet, and provide a complete physical picture of the universe's most engimatic objects.

AXAF will be a long-lived observatory designed for on-orbit instrument replacement and servicing. Between the Shuttle, and Space Station Freedom, the U.S. will have the unique capability to maintain this telescope in orbit. During 1988, Phase 2 of the Technology Mirror Assembly (TMA) was completed and TRW was selected as the prime contractor. Starting in FY 1989, Congress has implemented a phased implementation approach to the program. Development funding in the FY 1989-1991 timeframe has been reduced, limiting nearterm development activities to the High Resolution Mirror Assembly/X-ray Telescope

Assembly (HRMA/XTA) and the science instruments. Funding was also provided in Research and Analysis under Advanced Technology Development (ATD) to support other activities such as observatory definition, long-lead parts procurements and design studies leading to anticipated full-scale initiation of observatory development in FY 1992. This has resulted in a 6 month delay in launch readiness from December 1995 to June 1996.

CHANGES IN FY 1989 BUDGET ESTIMATE

The $11.0 million reduction reflects the phased implementation approach as directed by Congress.

BASIS OF FY 1990 ESTIMATE

FY 1990 funding continues activities on the HRMA/XTA, with particular emphasis on completion of the largest and most challenging set of parabolic/hyperbolic mirrors (P1/H1). Science instrument development will be initiated during FY 1990.

BASIS OF FY 1990 FUNDING REOUIREMENT

PAYLOAD AND INSTRUMENT DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Collaborative solar terrestrial research.	14,900	43,900	43,900	54,800
Tether satellite systems..................	3,400	3,700	7,700	6,200
Shuttle test of relativity experiment (GP-B)................................	10,300	22,000	17,900	--
Astrophysics payloads...................	8,100	5,500	9,600	7,200
Space physics payloads...................	9,900	2.000	2.600	3.200
Total.................................	46.600	77.100	81.700	71.400

OBJECTIVES AND STATUS

Instrument development activities support a wide range of instrumentation - from early test, checkout and design of instruments for long-duration free-flying missions to international flights of opportunity. The Collaborative Solar Terrestrial Research Program (COSTR) will provide state-of-the-art instrumentation for flight opportunities on international spacecraft and various U.S. spacecraft of opportunity. Emphasis is on developing scientific instruments conceived through the Space Physics Research and Analysis and Sounding Rocket programs. Instruments to be developed in the near term will provide a U.S. contribution to an international thrust in space physics research in the 1989-1995 timeframe, principally, the European Solar Terrestrial Science Programme (STSP) and the Japanese Geotail Mission.

The Tether Satellite System (TSS), scheduled for launch in FY 1991, will provide a facility for conducting experiments weighing 500 kg or less from distances of 100 km above or below the Space Shuttle. The objective of the initial TSS mission (TSS-1) is to verify the controlled deployment, retrieval and on-station stabilization of a satellite tethered from the Space Shuttle orbiter, and to carry out an electrodynamics experiment using a conducting tether extended 20 km above the orbiter. TSS-1 is an international cooperative project with the Italian government. The U.S. is responsible for overall project management, system integration, developing the tether deployment and retrieval system, developing and integrating U.S.-provided instruments, and flight on the Shuttle. Italy is developing the satellite and is responsible for development and integration of Italian-provided instruments.

Astrophysics and Space Physics Payloads include a number of instruments designed for flight on the STS and ELV's. Emphasis will be on instrument development for study of the complex relationships of solar irradiance and the near-Earth plasma environment (Atmospheric Laboratory for Applications and Science - ATLAS), and the diffuse x-ray background and spectra of point and extended sources (Shuttle High Energy Astrophysics Lab - SHEAL).

The Shuttle test flight of the Gravity Probe-B instrument involves the development of a multigyroscope experimentation package to fly as an attached payload on the Shuttle in 1993, as an integral part of the study of relativity. Due to the constraints placed on the agency's FY 1990 budget and the limited growth possibilities for future years, OSSA plans to terminate ongoing efforts in this program after FY 1989.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Imaging Spectrometic Observatory (ISO) development activities, previously funded under Environmental Observations Payload program, have been transferred to the Space Physics Payloads program. Tether payloads has increased in order to accommodate cost growth on the prime contract.

The Shuttle test flight of the Gravity Probe-B instrument was reduced by $4.1 million in order to fund other OSSA requirements. Remaining funds will provide for termination of the program.

Other payload activities have been accelerated due to changes in the STS flight manifest. In particular, the Broad Band X-ray Telescope (BBXRT) is being accelerated in the manifest by two years, and will fly a second mission.

BASIS FOR FY 1990 ESTIMATE

In FY 1990, the COSTR program will continue development of U.S.-provided instruments for the ISAS/NASA Geotail mission which will explore the Earth's magnetosphere and deep geotail region. NASA will also be developing U.S.-provided instruments and mission support equipment for the ESA/NASA joint Cluster and SOHO missions, which will provide unique capabilities for measurement of solar oscillations and solar corona. Funding is also required to continue development of U.S.-provided instruments and for core equipment development and integration on TSS-1. Funding will also continue to support the development of Astro-1 and SHEAL-2 payloads which will fly in FY 1990 and FY 1992 respectively. In addition, alternate launch opportunities will be sought for applicable payloads.

BASIS OF FY 1990 FUNDING REQUIREMENT

SHUTTLE/SPACELAB/PAYLOAD MISSION MANAGEMENT AND INTEGRATION

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Shuttle/Spacelab payload mission management and integration.............	47,800	61,500	69,700	86,100

OBJECTIVES AND STATUS

The primary objective of the Spacelab Payload Mission Management program is to manage the mission planning, integration, and execution of all NASA Spacelab and attached Shuttle payloads. This includes system management and engineering development of flight support equipment and software; development of certain interface hardware; payload specialist training and support; integration of the science payloads with the Spacelab system; payload flight operations; and data dissemination to experimenters.

Mission management activities are continuing for Physics and Astronomy missions including the Astro-1 mission and the Shuttle High Energy Astrophysics Lab (SHEAL). Astro-1 is scheduled for flight in FY 1990; SHEAL is currently planned for flight in N 1992. The primary instrument on SHEAL, the Broad-Band X-ray Telescope (BBXRT) is also under accelerated development to accommodate an earlier flight of the Astro mission, in order to make timely observations of the Supernova 1987a.

Mission management activities are continuing on several other space science and applications missions, such as the Atmospheric Laboratory for Applications and Science (ATLAS). The first of this series is planned for flight in 1990. The mission will incorporate a large number of instruments designed to study the complex relationships of solar irradiance, atmospheric composition and changes, and the near-earth plasma environment. Other missions include flight of an imaging radar in the early 1990's; a series of Spacelab Life Sciences missions (SLS), the first scheduled for launch in June 1990; a joint microgravity mission with the Japanese (SL-J); a series of cooperative International Microgravity Laboratories (IML's); and flight of the ongoing series of Materials Science Laboratories (MSL's) and U.S. Microgravity Laboratories (USML's). Currently under consideration is a United States Microgravity Payload (USMP) series, which will incorporate and expand the MSL missions in order to maximize materials processing capabilities in space. Mission management activities also support other (non-OSSA) payloads. For example, the Space Station heat pipe advanced radiator element experiment payload will test a heat rejection system with high potential for future spaceborne applications.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The major driver behind changes to the FY 1989 budget was the acceleration of most of the Spacelab missions manifested on the Shuttle. While the manifest change generally resulted in a reduced cost per mission, the intensified manpower demanded by the acceleration required additional nearterm funding. Other changes include the accelerated development of the pointing system on which the **BBXRT** is mounted.

BASIS OF FY 1990 ESTIMATE

Mission management activities will escalate in FY 1990 as Spacelab missions resume with the flight of Astro-1 in FY 1990. Integration, testing, and evaluation will continue for other major Shuttle/Spacelab missions including SHEAL-2, the ATLAS series, the Spacelab Life Science (SLS) missions, the International Microgravity Laboratories (IML), as well as a new German Spacelab follow-on. In addition, alternate launch opportunities will be sought for applicable payloads.

BASIS OF FY 1990 FUNDING REQUIREMENT

SPACE STATION INTEGRATION PLANNING AND ATTACHED PAYLOADS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Space station integration planning and attached payloads......................	18,900	8,000	8,000	23,000

OBJECTIVES AND STATUS

The primary objective of the Space Station Integration Planning and Attached Payloads program is to provide the necessary planning, definition and development of payloads and missions as the Office of Space Science and Applications prepares for future uses of the Space Station complex. This includes the definition of attached payloads suitable for deployment on the early Space Station, as well as the definition of integration and operational requirements, in anticipation of the new, integrated methods of conducting scientific research which the Space Station will offer.

Studies continue to define the end-to-end science operations requirement for the Space Station era (i.e., the cycle from identification of science requirements, through mission planning and operations to dissemination, analysis and archiving of data). Studies also continue to determine the best use of Space Station resources (such as, power, crew time, volume, data handling capabilities, pointing capabilities) in terms of science requirements. Potential attached payloads have been identified for further feasibility and definition and appropriate studies are underway; Announcements of Opportunity selections for Attached Payloads will be issued in FY 1989.

BASIS OF FY 1990 ESTIMATE

In FY 1990, definition and development will continue on those attached payloads selected for early flight on the Space Station. In addition, an augmentation of $5 million has been added to support mission management activities such as operations support and accommodations and requirements analysis. This augmentation will also include study and analysis of Space Station Information Systems integration.

BASIS OF FY 1990 FUNDING REOUIREMENT

EXPLORER DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Cosmic background explorer...............	16,600	5,500	10,600	--
Extreme ultraviolet explorer.............	29,400	40,400	41,400	45,800
Roentgen satellite experiments...........	1,400	3,300	3,700	1,700
Combined release and radiation effects satellite experiments..................	2,200	2,200	2,200	2,200
Solar-A................................	7,600	4,600	4,600	3,200
Other explorers........................	10,700	26,100	19,600	40,300
Total................................	67,900	82,100	82,100	93,200

OBJECTIVES AND STATUS

Investigations selected for Explorers are usually of an exploratory or survey nature, or have specific objectives not requiring the capabilities of a major observatory. Past Explorers have discovered radiation trapped within the Earth's magnetic field, investigated the solar wind and its interaction with the Earth, studied upper atmosphere dynamics and chemistry, mapped our galaxy in radio waves and gamma-rays, and determined the properties of the interstellar medium through ultraviolet observations. Recent Explorers have performed active plasma experiments on the magnetosphere, made in-situ measurements of the comet Giacobini-Zinner, and completed the first high sensitivity, all-sky survey in the infrared, discovering over 300,000 sources.

Explorers under development will study the properties of the cosmic microwave background, which is important for understanding the early universe and cosmology, survey the sky in the extreme ultraviolet for the first time, and measure time-variable phenomena in x-ray sources. The Explorer program also provides a means of developing instruments for "payload-of-opportunity" missions, such as those involving other Federal agencies or international collaboration.

The San Marco-D mission, a cooperative project with Italy, was launched in March 1988 on a Scout expendable launch vehicle to study the relationship between solar activity and meteorological phenomena on the Earth. After successfully completing its mission objective, the spacecraft reentered the Earth's atmosphere in December 1988. The Cosmic-Ray Isotope Experiment (CRIE) will be included in the Combined

Release and Radiation Effects Satellite (CRRES), a joint NASA/DOD mission, now scheduled for an Atlas-Centaur launch to a geosynchronous transfer orbit (GTO) in FY 1990. The CRRES GTO mission will also release trace chemicals, whose transport in the magnetosphere can be observed from ground and airborne-based instruments,

Current plans call for the launch of the Cosmic Background Explorer (COBE) in FY 1989. COBE will carry out a definitive, all-sky exploration of the infrared background radiation of the universe between the wavelengths of one micrometer and 9.6 millimeters.

In FY 1989, development continues on the Extreme Ultraviolet Explorer (EUVE), and on the x-ray imaging instrument to be flown on the German Roentgen Satellite (ROSAT). EWE, scheduled for launch on a Delta ELV in FY 1991, will carry out the first detailed all-sky survey of extreme ultraviolet radiation between 100 and 900 angstroms. ROSAT, a cooperative project between the Federal Republic of Germany (FRG) and the United States will perform a high resolution imaging survey of the x-ray sky and provide in-depth studies on selected objects. The U.S. will provide one of the ROSAT instruments and the launch services; Germany will provide the spacecraft, telescope, and other instruments. Current plans call for ROSAT to be launched on a Delta ELV also in FY 1990.

In FY 1986, a new cooperative mission called Solar-A was initiated with the Japanese. Solar-A will be launched in FY 1991 to study the Sun during the upcoming solar maximum. The U.S. has selected an instrument for this spacecraft, which will relate energetic solar phenomena and dynamic coronal structures seen in hard and soft x-rays to the topology of evolving solar magnetic fields. This will allow the first simultaneous observations of these phenomena from space.

Definition and design will continue in FY 1989 on the X-ray Timing Explorer (XTE). This mission can be ready for launch as early as FY 1994. During FY 1986, a "Dear Colleague" letter was issued to obtain proposals for future Explorers. Over *43* were received and four candidate missions--the Advanced Composition Explorer (ACE), Far Ultraviolet Spectroscopy Explorer (FUSE), Mesophere/Lower Thermosphere Explorer (MELTER) and the Nuclear Astrophysics Explorer (NAE)--were selected for further definition.

In addition to the traditional Delta-class explorers, the Explorer program will begin development of "small class" explorers. While subject to more stringent constraints than Delta-class missions (weight, telemetry, power, etc.), it is anticipated that a significant number of scientifically exciting missions can utilize this capability and be developed on a short timescale. Following a peer review of proposals, it is anticipated that several small-class missions will be selected for development with the initial one being launched as early as FY 1991. In addition, alternate launch opportunities will be sought for applicable payloads.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The planned launch of the Cosmic Background Explorer has been delayed four months due to instrument development problems. Additional funds for COBE, as well as minor increases for EUVE and ROSAT, were made available by rephasing XTE requirements.

BASIS OF FY 1990 ESTIMATE

During FY 1990, development activity will continue on EUVE and on instruments scheduled to fly on CRRES, ROSAT, Solar-A, Astro-D and the first small-class explorer mission. Development activities will also begin on XTE.

BASIS OF FY 1990 FUNDING REOUIREMENT

MISSION OPERATIONS AND DATA ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Hubble space telescope operations........	51,200	59,100	--	--
Hubble space telescope maintenance and refurbishment.........................	48,000	52,200	--	--
Hubble space telescope operations and servicing.........................	--	--	88,500	113,200
Hubble space telescope data analysis.....	--	--	9,800	21,200
Astrophysics mission operations and data analysis.........................	22,700	29,300	33,300	54,500
Space physics mission operations and data analysis.........................	18.600	15,600	11.600	15.900
Total.................................	140.500	156.200	143.200	204.800

OBJECTIVES AND STATUS

The purpose of the Mission Operations and Data Analysis (MO&DA) effort is to conduct operations and analyze data received from physics and astronomy spacecraft after launch. The program also supports the operation of a number of spacecraft after their originally planned objectives have been achieved, for purposes of conducting specific investigations that have continuing high scientific significance. The funding supports the data analysis activities of the many investigators at universities and other research organizations associated with astrophysics and space physics operational satellite projects. Actual satellite operations, including control centers and related data reduction and engineering support activities, are typically carried out under a variety of mission support or center support contracts.

Space Physics research activities rely on data received from the Interplanetary Monitoring Platform (IMP), the Active Magnetospheric Particle Trace Explorer (AMPTE), the Dynamics Explorer (DE) which are still operational, and the International Sun Earth Explorers (ISEE-1&2) which reentered the Earth's atmosphere in October 1987. IMP continues to provide the only available source of solar wind input measurements to the Earth. IMP, along with ISEE-1&2, DE, AMPTE, and the Swedish Viking satellite successfully conducted a multisatellite campaign called Polar Regions and Outer Magnetospheric

International Study (PROMIS) in **1986**. The ISEE-3 spacecraft, renamed the International Cometery Explorer (ICE), provided complementary solar wind measurements upstream of Comet Halley in **1986**, and was retargeted for a return to Earth orbit in *2014* for retrieval and presentation to the National Air and Space Museum (NASM).

In addition to the normal support required for mission operations, the Hubble Space Telescope (HST) program encompasses several unique aspects which must be provided for in advance of the launch. The HST is designed to operate for more than a decade, using the Space Shuttle/Orbital Maneuvering Vehicle combination and/or Space Station for on-orbit maintenance of the spacecraft and in-orbit changeout or repair of the scientific instruments. In order to reduce the likely servicing requirements of the HST, development was initiated on Nickel-Hydrogen batteries and Back Surface Field Reflecting Solar arrays to improve the power lifetime of the spacecraft.

The HST will be used primarily by observers selected on the basis of proposals submitted in response to periodic solicitations. Science operations will be carried out through the independent HST Science Institute. The Institute operates under a long-term contract with NASA. While NASA retains operational responsibility for the observatory, the Institute implements NASA policies in the area of planning, management, and scheduling of the scientific operations of the HST.

Initiation of the definition and implementation of a unified data system which will ensure the fullest access and exploitation of the various mission data sets, with emphasis on the wealth of data to be returned by the Great Observatories, will be undertaken. An initial definition process involving extensive inputs from the astrophysics community has now been completed, and FY **1989** funding in the MO&DA program will enable the principal elements of this essential system to be put in place.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The HST MO&DA program has been restructured in order to separate science support to investigators and archival researchers from the tradeoffs associated with the operations and servicing of HST. HST MO&DA has been reduced by $13.0 million, $10 million of which was consistent with specific Congressional direction. The balance provides for increased Spacelab mission management requirements associated with the revised STS manifest. Space Physics mission funding has been reduced in order to accommodate cost growth in the Tether Satellite Systems project. Astrophysics MO&DA has been increased *$4.0* million to fund a more robust archival data analysis program.

BASIS OF FY 1990 ESTIMATE

The FY **1990** funding level is required to maintain critical skills for the operation and maintenance of the Hubble Space Telescope, and to prepare for launch activities in **FY 1990**.

The FY 1990 budget will also support initial mission operations and data analysis for the Gamma Ray Observatory, scheduled for launch in FY 1990, the Cosmic Background Explorer (COBE), scheduled for launch in FY 1989 and ROSAT, also scheduled for launch in FY 1990.

Mission operations, data analysis, and guest investigator programs will continue for the Solar Maximum Mission (SMM), the Interplanetary Monitoring Platform (IMP), the Dynamics Explorer (DE), the Active Magnetospheric Particle Trace Explorer (AMPTE), International Cometary Explorer (ICE), and the International Ultraviolet Explorer (IUE). The High Energy Astronomical Observatories (HEAO 1-3), International Sun-Earth Explorers 1 and 2 (ISEE-1 & 2), and the Infrared Astronomy Satellite (IRAS) data analysis will also continue. These programs have produced valuable data sets which are used by a wide segment of the science community. FY 1990 funds will also be used to continue development of the unified astrophysics data system.

BASIS OF FY 1990 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Supporting research and technology.......	69,700	84,800	85,800	101,500
Advanced technology development..........	13.200	4.300	--	11,000
Total........................	82.900	89,100	85.800	112.500

OBJECTIVES AND STATUS

This program provides for the preliminary studies required to define missions and/or payload requirements, as well as providing a research and technology base necessary to define, plan and support flight projects.

Supporting Research and Technology (SR&T): The objectives of supporting research and technology are to: (1) optimize the return expected from future missions through scientific problem definition, development of advanced instrumentation and concepts, and sound definition of proposed new missions; (2) enhance the value of current space missions by carrying out complementary and supplementary ground-based observations and laboratory experiments; (3) develop theories to explain observed phenomena and predict new ones; (4) strengthen the technological base for sensor and instrumentation development and conduct the basic research necessary to understand astrophysics phenomena and solar-terrestrial relationships; and, (5) continue the acquisition, analysis and evaluation of data from laboratories, balloons, rocket and spacecraft activities.

Research is supported in the disciplines of astronomy; astrophysics; and gravitational, plasma, cosmic ray and solar physics. Research in astronomy and astrophysics involves the study of stars, galaxies, interstellar and intergalactic matter, and cosmic rays. Space physics research and analysis is a broadly structured effort to enhance our understanding of the characteristics and behavior of plasmas in the solar corona, the interplanetary medium and in the vicinity of the Earth and other planets. Theory activities are related to all the Physics and Astronomy disciplines and are critical to the correlation of available information. The development of new instruments, laboratory and theoretical studies of basic physical processes, and observations by ground-based and balloon-borne instruments will also be continued. Results achieved in the SR&T program will have a direct bearing on future flight programs. For example, the development of advanced x-ray, ultraviolet, and infrared astronomy imaging devices under this program may enable spacecraft to carry instruments for astronomical observations which have increased orders of magnitude in sensitivity and improved resolution over currently available detectors.

One major thrust of the space physics program is directed at studies of the near-Earth geospace environment, from the flow of the solar wind past the magnetosphere, to variations in the plasma environment detectable near the surface of the Earth. Not only are these studies of great interest for basic plasma physics but there are also many practical ramifications, such as ionospheric influences on communication, global circulation of the atmosphere driven by magnetospheric input, the charging of spacecraft immersed in plasma, and the behavior of antennas and their signals in the magnetosphere.

The SR&T program carries out its objectives through universities, nonprofit and industrial research institutions, NASA centers and other government agencies. Current emphasis is being placed on studies of advanced instrumentation with increased sensitivity and resolution.

Advanced Technological Development (ATD): The Advanced Technological Development (ATD) activities support detailed planning and definition of potential new physics and astronomy missions. ATD activities assure that future missions address the scientific questions most important to the evolution of knowledge in the field, and that those missions use the appropriate technology and techniques. FY 1989 activities continue the study of a Stratospheric Observatory For Infrared Astronomy (SOFIA) as potential follow-on for the C-141 in the 1990s. SOFIA would incorporate a 3-meter class infrared telescope mounted in a suitable aircraft.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The $3.3 million decrease reflects a transfer of ATD funding to high-priority Astrophysics MO&DA and SR&T activities.

BASIS OF FY 1990 ESTIMATE

During FY 1990, the supporting research and technology program will support those tasks which contribute to maintaining a firm base for viable physics and astronomy and space physics programs. FY 1990 funding will support continued studies on potential future missions. In the data analysis activities to be carried out at university and government research centers in FY 1990, emphasis will be placed on correlative studies involving data acquired from several sources (spacecraft, balloons, sounding rockets, research aircraft and ground observatories). ATD funding will support the AXAF observatory definition, long-lead procurements and design studies at the mission contractor, TRW, Inc., leading to anticipated full-scale initiation of observatory development in FY 1992.

BASIS OF FY 1990 FUNDING REQUIREMENT

SUBORBITAL PROGRAM

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Sounding rockets........................	27,500	28,700	27,000	30,500
Airborne science and applications........	7,300	7,800	9,800	10,900
Balloon program.........................	9.900	8.600	8.600	12.100
Total............................	44.700	45.100	45.400	53.500

OBJECTIVES AND STATUS

The suborbital program uses balloons, aircraft, and sounding rockets to conduct versatile, relatively low-cost research of the Earth's ionosphere and magnetosphere, space plasma physics, stellar astronomy, solar astronomy, and high energy astrophysics. Activities are conducted on both a national and international cooperative basis.

Sounding Rockets: A major objective of the sounding rocket program is to support a coordinated research effort. Sounding rockets are uniquely suited for performing low altitude measurements (between balloon and spacecraft altitude) and for measuring vertical variations of many atmospheric parameters. Special areas of study supported by the sounding rocket program include the nature, characteristics, and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including the production of aurorae and the coupling of energy into the atmosphere; and the nature, characteristics, and spectra of radiation of the Sun, stars and other celestial objects. Also included is support for NASA's final Spartan mission, Spartan 201, which consists of a 17-inch diameter solar telescope with an ultraviolet coronagraph and a white light coronagraph to measure the intensity and scattering properties of solar light. Spartan 201 is planned for Shuttle launch in the early 1990s.

Additionally, the sounding rocket program provides several OSSA programs with the means for flight testing instruments being developed for future flight missions. The program also provides a means for calibrating flight instruments and obtaining vertical atmospheric profiles to complement data obtained from orbiting spacecraft. Approximately forty rockets are scheduled for launch in FY 1989.

Airborne Science and Applications: Research with instrumented jet aircraft has been an integral part of the NASA physics and astronomy program since 1965. For astronomy research, the airborne science and applications program operates the Kuiper Airborne Observatory (KAO). This full-scale manned facility consists of a ***C-141*** aircraft equipped with a 91 centimeter infrared telescope. The ***C-141's*** ability to fly for several hours at altitudes approaching 13 kilometers provides a cloud-free site for astronomical observations above most of the infrared-absorbing water vapor in the Earth's atmosphere. This has been essential in expanding astronomical observations into the infrared region of the electromagnetic spectrum from one micrometer to hundreds of micrometers.

In FY 1988, the ***C-141*** conducted two major campaigns in the southern hemisphere to study Supernova SN1987a. The ***C-141*** played a critical role in the continual effort to characterize the Supernova by measuring its velocity, morphology and composition. During 1988, the ***C-141*** also conducted studies of the Sun's upper atmosphere and observed a stellar occultation by the planet Pluto which provided the first experimental evidence of the existence of an atmosphere on that planet. Other observations included the exploration of star-forming regions and other areas in our own galaxy and solar system. In FY 1989, 72 missions are planned, including support of the SN1987a campaign with additional flights in the southern hemisphere.

Balloon Program: The Balloon program provides a cost-effective means to test flight instrumentation in the space radiation environment and for making observations at altitudes which are above most of the water vapor in the atmosphere. Balloon experimentation is particularly useful when studying infrared, gamma-ray, and cosmic-ray astronomy. In many instances it is necessary, because of size, weight, cost, or lack of other opportunities, to fly primary scientific experiments on balloons. In addition to the level-of-effort science observations program, significant emphasis has been and will be placed on development of a balloon capable of lifting more than 3,500 pounds, and to support missions lasting several days.

The Balloon program funding is required for purchase of balloons, helium, launch services, tracking and recovery, as well as for maintenance and operations of the National Scientific Balloon Facility (NSBF) at Palestine, Texas and remote launch sites. Funding for the experiments flown on balloons is provided from other research and technology programs supporting the various scientific disciplines.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Sounding Rocket funding has been reduced by $1.7 million in order to support Spacelab mission management activities associated with the revised STS manifest. The airborne program was increased by $2.0 million to meet additional aircraft maintenance and operations requirements for the KAO.

BASIS OF FY 1990 ESTIMATE

FY 1990 funds will provide for continuation of the sounding rocket, Spartan, and balloon programs including management and operation of the NSBF. This funding is also required to continue definition activities for balloon improvement and long-duration balloon flights. In FY 1990, the Airborne Science and Applications funding will be used to continue flights of the KAO. In addition, alternate launch opportunities will be sought for applicable payloads.

LIFE SCIENCES

LIFE SCIENCES

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

SPACE LIFE SCIENCES PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Human space flight and systems engineering	--	--	27,600	42,800	RD 4-4
Space biological sciences	--	--	10,100	27,600	RD 4-4
Life sciences flight experiments	33,800	54,500	--	--	RD 4-4
Research and analysis	38.400	47.200	40.400	53.800	RD 4-7
Total	72.200	101.700	78.100	124.200	

Distribution of Program Amount by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center	29,200	32,300	30,700	47,800
Kennedy Space Center	3,000	4,200	3,100	3,900
Goddard Space Flight Center	200	300	200	200
Jet Propulsion Laboratory	1,100	3,700	1,100	2,300
Ames Research Center	26,900	44,300	28,700	50,700
Langley Research Center	500	600	500	500
Marshall Space Flight Center	100	200	100	100
Stennis Space Center	100	100	100	100
Headquarters	11.100	16.000	13.600	18.600
Total	72.200	101.700	78,100	124.200

PROGRAM OBJECTIVE AND JUSTIFICATION

The goals of the Space Life Sciences program are to advance knowledge in all areas of space life sciences and to develop medical and biological systems which enable human habitation in space. Results from the research program are applied to: the immediate needs of maintaining astronaut health and productivity; understanding the response of biological mechanisms to weightlessness; the design of controlled ecological life support systems; understanding the origin, evolution and distribution of life in the universe; and, understanding the biosphere of the planet Earth.

Continuing support of the Space Life Sciences program is essential to: understand the basic biological mechanisms of gravitational responsivity; evolve the critical technologies necessary to enable long-term piloted space flight; and, develop the capability to sustain a permanent manned presence in space. The research program includes ground-based and space research efforts which are mutually supportive and integrated, and the study of fundamental biological processes and space-related medical problems through a variety of disciplines and techniques.

The Space Life Sciences research and analysis program includes five major elements: 1) space medicine, which addresses the health and well-being of space crews by seeking to understand and prevent adverse physiological changes which occur in space flight and upon return to Earth; 2) space biology, an integrated basic science research program that studies the fundamental mechanisms of gravitational interaction with all orders of plants and animals in flight and ground experiments; 3) controlled ecological life support systems, a program of research and critical technology development for life support systems necessary to maintain life in space autonomously for long periods of time; 4) exobiology research, which is directed toward understanding the origin and distribution of life and life-related molecules on Earth and throughout the universe; and, 5) biospheric research, which explores the interaction between life on Earth and its physical and chemical environment.

The Space Life Sciences flight program, provides scientific and engineering support to select, define, develop, conduct and report on in-space experiments, and data analysis of medical and biological investigations involving humans, animals and plants. The flight program is actively preparing experiments for launch on Spacelab missions in FY 1990 and FY 1991. Definition activities are underway to develop payloads for later Spacelab missions and early Space Station utilization. An international cooperative program, the U.S./U.S.S.R. working group in space biology and medicine, pursues investigations of joint interest.

Beginning in FY 1989 the Life Sciences flight experiments program has been restructured into two categories: human space flight and systems engineering, and space biological sciences. The major focus of the human space flight and systems engineering program is to ensure effective Shuttle and Space Station crew performance. The space biological space program with pursue the basic plant, animal, and human research necessary to support a broad based space biology program including those areas of research which are essential to the human space flight and systems engineering program.

BASIS OF FY 1990 FUNDING REQUIREMENT

SPACE LIFE SCIENCES FLIGHT PROGRAM

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Human space flight and systems engineering..........................	--	--	27,600	42,800
Space biological sciences................	--	--	10,100	27,600
Life sciences flight experiments.........	33,800	54,500	--	--
Total..............................	33,800	54,500	37,700	70,400

OBJECTIVES AND STATUS

The objective of the Space Life Sciences flight program is to assimilate information and scientific questions from various life science disciplines and develop payloads designed to expand the understanding of the basic physiological mechanisms involved in adaptation of weightlessness. The program includes selection, definition, in-flight execution, data analysis and reporting on medical and biological investigations involving humans, animals and plants. Human space flight and systems engineering activities further NASA's ability to extend the duration, enhance the performance, and improve the safety of human space flight. Past experience indicates that humans clearly undergo physiological changes during weightlessness. Many of the observed changes are physiologically significant and are not well understood. Shuttle/Spacelab and Space Station missions are suitable for gaining a greater understanding of the basic mechanisms underlying this response to weightlessness. Space Biological Sciences flight activities use the space environment, especially weightlessness, to further basic understanding of fundamental biological processes. Such flight experiments lead to a firmer comprehension of the underlying mechanisms of gravitational adaptation, enhance our basic science knowledge, make it possible to improve the management of several existing problems, and increase the confidence with which we can estimate the physiological consequences of more sustained weightless exposure and design corresponding countermeasures. Another key area of research in space biological sciences is exobiology.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The $16.8 million dollar reduction is consistent with Congressional direction. It was accommodated by the delay of the Spacelab centrifuge development by one year; reduced support for definition of the Space

Biology Initiative (SBI) and Extended Duration Crew Operations (EDCO) programs; and reduced principal investigator support and science on manifested Spacelab missions.

BASIS OF FY 1990 ESTIMATE

The human space flight and systems engineering and space biological sciences programs are included in the resumption of Life Sciences Space Transportation Systems (STS) missions starting in FY 1990. The FY 1990 budget supports the increase in flight program activity.

FY 1990 funding is required for the final preparation and flight of approved experiments on the first dedicated Life Science mission (Spacelab Life Sciences-1 (SLS-1)) which is scheduled to be launched in June 1990 and will concentrate on studies of human and animal biomedical responses, with emphasis on cardiovascular, bone metabolism and vestibular functions. SLS-1 will be unique in several respects: it will be the first Shuttle/Spacelab mission dedicated entirely to life sciences, and it will involve highly skilled scientists as payload specialists, thus permitting the use of numerous experimental techniques and procedures never before utilized in space. Many of the experiments and associated flight hardware flown on earlier Shuttle flights will support and enhance preparations for SLS-1 and subsequent missions.

Final preparations are also underway to support the flight of the first International Microgravity Laboratory (IML-1) mission in 1991. Approximately 50 percent of the payload relates to space life sciences, with the U.S. focus on plants, neurovestibular studies, human performance, radiation and cellular differentiation.

Efforts will continue on definition and development of new experiments (selected through the Announcement of Opportunity (AO) process) and hardware that will be flown on future Spacelab/Shuttle missions in FY 1991 and 1992 - i.e., Shuttle mid-decks, the Japanese SL-J mission, the second dedicated life sciences mission (SLS-2), the German D-2 mission, IML-2 and SLS-3. Collaboration with the Soviet Union on its COSMOS biosatellite program will continue with joint research planned on COSMOS flights in 1989 and 1991. Phase B studies continue on the reusable reentry satellite (RRS) for life sciences research, and NASA is coordinating development of the RRS with several international partners.

In FY 1990, under the Human Space Flight and Systems Engineering program, efforts will continue in a major new area of research - ensuring effective Shuttle crew performance on-orbit and during landing on extended duration orbiter missions. Investigations will proceed on Spacelab and middeck experiments with the operational goal of enabling long duration missions in time for the U.S. Microgravity Lab-1 mission planned for 1992. Research efforts will also be focused on extending operational tours of duty of flight crews on the Space Station in order to achieve greater cost-effectiveness. This program is required to meet the four to five yearly Shuttle flights assumed in the Space Station baseline program. It will also allow more effective use of human resources by developing countermeasures that maintain crew health and productivity and minimize impact on in-flight crew time. Crew debility and rehabilitation time following long duration space flight will also be reduced. Spacelab opportunities will be used to conduct supporting experiments and fly associated payloads. Preparation for the Space Station will commence with investigation planning, technology assessment for flight equipment, and critical technology and hardware development.

In FY 1990, under the Space Biological Sciences program, the detailed definition and development phase will begin on an integrated centrifuge facility for Spacelab that will support a broad spectrum of life sciences research using small animals and plants. For the first time, it will provide continuous on-board 1-G control that can separate influences of weightlessness from other effects of space flight. It will allow scientists to test the response of living organisms to operational forces at various stages of adaptation to weightlessness. The centrifuge will be deployed on Spacelab where in-flight engineering verifications for the centrifuge, associated equipment and logistical support will be performed. The Spacelab centrifuge will provide a testbed for subsequent development of a Space Station Centrifuge. This facility represents a marked enhancement of basic research capability for the Life Sciences program.

In FY 1990, studies will be conducted in the Space Biological Sciences Program to determine how space biology research will be accommodated on the Space Station, as well as to define instrument and facility requirements. Studies will identify unique scientific and hardware transition requirements from continuing Spacelab flights into Space Station Freedom operations. In addition, technology assessment, advanced technology development, hardware definition, and experiment definition and planning will be conducted.

BASIS OF FY 1990 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Space life sciences research and analysis	38,400	47,200	40,400	53,800

OBJECTIVES AND STATUS

The research and analysis activity supports Space Life Sciences program goals of: advancing knowledge in all areas of space life sciences and developing medical and biological systems which enable human habitation in space. The program is composed of five elements: 1) space medicine; 2) space biology; 3) controlled ecological life support systems research; 4) exobiology; and, 5) biospheric research.

The Space Medicine program is responsible for assuring the physical welfare, performance and adequate treatment of in-flight illness or injuries of spaceflight crews. Such conditions as space motion sickness, spatial disorientation, fluid shifts and endocrine changes, can decrease performance and cardiovascular tolerance and possibly aggravate latent disease. These conditions must be carefully evaluated to determine preventative measures. To this end, careful medical selection, periodic evaluation of health status, and in-flight monitoring of the adaptation to space and success of physiological countermeasures will be continually undertaken. In addition, long-term monitoring of space flight crews will be performed in a standardized fashion in order to identify risk factors and establish the long-term clinical significance associated with repeated exposure to the space environment. Biomedical research will investigate the fundamental physiological basis for problems encountered in manned spaceflight. Research areas include: clinical medicine; neuroscience; cardiopulmonary, musculoskeletal, and regulatory physiology; cell and developmental biology; behavior, performance and human factors; and, radiation and environmental factors.

The Space Biology program explores the role of gravity in life processes and uses gravity variations as an environmental tool to investigate fundamental biological questions. Specific objectives are to perform the basic science research required to identify and investigate: 1) the role of gravity in plant and animal behavior, morphology, development and physiology; 2) the mechanisms of gravity sensing and the transmission of this information within both plants and animals; 3) the interactive effects of gravity and other stimuli (e.g., light) and stresses (e.g., vibration and disorientation) on the physiology of organisms; 4) the uses of gravity to study the normal nature and properties of living organisms; and, 5) the effects of microgravity to facilitate plant and animal growth, long-term survival and reproduction in space.

The Controlled Ecological Life Support Systems program seeks to provide air, water and food to support life through bioregenerative closed systems which receive only energy from the external environment. Development of such systems is a critical path element for long duration manned spaceflight and lunar colonization.

The Exobiology program is directed toward understanding the origin and evolution of life, and life-related molecules, on Earth and throughout the universe. Research seeks to trace the pathways leading from the origin of the universe through the major epochs in the evolution of living systems. Research encompasses: the cosmic evolution of the biogenic compounds, prebiotic evolution, early evolution of life, and evolution of advanced life. Emphasis is placed on understanding these processes in the context of the planetary and astrophysical environments in which they occurred. Flight experiments in Earth orbit and on planetary missions are important program elements. Theoretical and laboratory investigations are also included in this program to develop a better understanding of the conditions on Earth as related to early chemical and biological evolution.

The Biospheric Research program explores the interaction between global biological and planetary processes to develop an understanding of global biogeochemical cycles. Laboratory and field investigations are correlated with remote sensing data to characterize the influence of biological processes in global dynamics. Biospheric modeling efforts integrate biological data with atmospheric, climate, oceanic, terrestrial, and biogeochemical cycling data to reflect the state of the biosphere as a function of both natural and anthropogenic perturbations.

In addition to conducting its o m research and analysis program, the Office of Space Science and Applications collaborates with the Office of Aeronautics and Space Technology on the Project Pathfinder. Pathfinder supports research of critical path elements for long-term manned missions in order to inform policy makers of the requirements (as well as uncertainties, risks and technological issues) involved in such efforts as a lunar base or manned Mars mission. Life science research is directed to the Humans-in-Space element of Project Pathfinder and focuses on the areas of human performance, extravehicular activity and life support. Critical areas of investigation in human performance include: biomedical requirements for artificial gravity; advanced medical care technology for remote locations; radiation protection; and psychological and habitability factors affecting crew behavior and performance on long duration missions. Research in extravehicular activity focuses on: developing requirements for portable life support systems and habitability of space suits; and gathering the anthropometric and bioengineering data needed to develop pressurized suit gloves that allow adequate manual dexterity. The Life Support program develops and tests technologies that will provide the capability for closed-loop life support. Important factors include waste processing, food production, air revitalization, and water purification.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The $6.8 million reduction is consistent with Congressional direction. It has been accomplished by delaying the development of the exobiology microwave observing project and reducing the support for principal investigators in the research and analysis program.

BASIS OF THE FY 1990 ESTIMATE

The Space Medicine program will collect information on occupational exposure in microgravity on each Shuttle flight and conduct in-flight clinical testing of countermeasures, especially in the area of vestibular dysfunction, cardiovascular deconditioning and muscular atrophy. Resolving problems associated with the initial adaptation to weightlessness such as space motion sickness and fluid shifts will continue to be of high priority. Research emphasis will be placed on operational management of space adaptation syndrome. Approaches such as autogenic (biofeedback) techniques will be evaluated in flight to provide a basis for development of specific countermeasures. Research will commence in the field of biomechanics. Understanding the dynamics of bodily adaptation to physical forces and being able to measure stress on the human body is crucial to designing countermeasures to maintain astronaut health, and productivity. Research in the fields of psychology and the ergonomics of man/machine interface will be supported for their importance in improving the performance and efficiency of flight crews. Research in radiation biology will continue because it is necessary to precisely measure dosages and the effects of cosmic and solar radiation in order to determine the optimum radiation shielding required for humans in space. Research is in progress to develop pressurized space suits for quick reaction situations and to develop corresponding pressurized suit gloves.

In conjuction with NASA's development of the Extended Duration Orbiter and the Space Station, the Space Medicine program will support extended crew time in space with extensive research in the physiological changes associated with longer exposure to weightlessness. Bone demineralization, muscle atrophy, neurovestibular disturbances and cardiovascular deconditioning will be studied in ground-based simulation so appropriate countermeasures can be designed. This accelerated program of directed research, bed rest studies and protocol development and evaluation will allow more effective use of human resources in space by developing physiological countermeasures that minimize impact on in-flight crew time. Critical technology requirements will be addressed and research focused on implementation initiated.

The Space Biology program will concentrate ground research on: developing working models of functioning gravity-sensing neural (information) networks to understand neurosensory processing in microgravity; understanding the physiological side effects of centrifugation in preparation for use of the Shuttle/Space Station centrifuge as a research tool; and identifying the cellular events of the gravity perception mechanism in plants. Research in preparation for flight opportunities on the Shuttle and the Soviet biosatellite COSMOS will focus on genetic, cytological, developmental and metabolic effects of gravity on plants and animals. Fundamental research in gravitational response mechanisms in plant and animal development will be developed in preparation for future biosatellite and Space Station experiments.

The Controlled Ecological Life Support Systems program will continue to investigate basic biological processes and physical methods to control the interior environment of manned spacecraft. In developing such a life support system, the near term emphasis will be on system definition and development of design concepts and critical technologies for flight, and supporting research in the areas of controlled-environment plant production, waste processing and human nutrition.

The Exobiology program will emphasize the development of new flight experiment concepts to investigate models of early Solar System evolution and mechanisms for the synthesis of biologically significant molecules in space. The program will further develop analytic capabilities to utilize an expanding extraterrestrial sample base, participate in the retrieval of samples, and focus science on emerging opportunities in planetary exploration. In FY 1990, definition and design phases will be completed in the program's microwave observing project which will analyze microwave signals in space for evidence of advanced life elsewhere in the galaxy. Funds will be used to begin the development phase of signal processing systems which will be used with existing radio astronomy facilities and NASA's Deep Space Network antennas.

The Biospheric Research program will place emphasis on improving estimation techniques for determining the structural state of the terrestrial biomass by combining ground-based measurements at tropical, temperate, and wetland sites with remote sensing data and biogeochemical modeling of the interactions of ecosystems on a global scale. Information gathered through remote sensing will also be used to help nations prepare for outbreaks of vector-borne disease (malaria) by allowing predictive modeling of the occurrence of the disease vector (mosquitoes).

In FY 1990, Specialized Centers of Research (SCOR) will be established at universities to support long-term, broad-based interdisciplinary research on selected high priority research topics. The SCOR program, which is modeled on the highly successful National Institutes of Health program, will help increase science results by concentrating resources, facilities and personnel on focused research problems. SCORs will conduct research in the following science programs: biomedical, operational medicine, space biology, exobiology, biospherics, and controlled ecological life support systems.

PLANETARY
EXPLORATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — PLANETARY EXPLORATION PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
	(Thousands of Dollars)				
Galileo development	51,900	61,300	73,400	17,400	RD 5-5
Magellan	73,000	33,900	43,100	--	RD 5-7
Ulysses	7,800	10,300	10,300	14,500	RD 5-9
Mars observer	53,900	102,200	102,200	100,500	RD 5-11
Comet rendezvous asteroid flyby/Cassini	--	--	--	30,000	RD 5-13
Mission operations and data analysis	73,792	112,700	110,700	155,400	RD 5-15
Research and analysis	67,308	83,600	76,900	79,100	RD 5-17
Total	327,700	404,000	416,600	396,900	

Distribution of Program Amount by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center	10,828	io,a55	9,312	9,100
Marshall Space Flight Center	158	245	134	150
Goddard Space Flight Center	9,757	9,710	17,870	17,500
Jet Propulsion Laboratory	247,421	325,300	326,324	308,950
Ames Research Center	14,757	15,795	15,074	13,700
Lewis Research Center	--	--	--	--
Langley Research Center	13	15	25	--
Headquarters	44,766	42,080	47,861	47,500
Total	327,700	404,000	416,600	396,900

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS **PLANETARY EXPLORATION PROGRAM**

PROGRAM OBJECTIVES AND JUSTIFICATION

The Planetary Exploration program encompasses the scientific exploration of the solar system including the planets and their satellites, comets and asteroids, and the interplanetary medium. The program objectives are: (1) to determine the nature of planets, comets, and asteroids as a means for understanding the origin and evolution of the solar system; (2) to better understand the Earth through comparative studies with the other planets; (3) to understand how the appearance of life in the solar system is related to the chemical history of the solar system; and, (4) to provide a scientific basis for the future use of resources available in near-Earth space. Projects undertaken in the past have been highly successful based on a strategy that places a balanced emphasis on the Earth-like inner planets, the giant gaseous outer planets, and the smaller bodies (comets and asteroids). Missions to these bodies start at the level of reconnaissance to achieve a fundamental characterization of the bodies, and then proceed to levels of more detailed study.

The reconnaissance phase of inner planet exploration, which began in the 1960's, is now virtually completed, although we still know little about the nature of the planet Venus' surface. Mars has provided program focus because of its potential as a site of biological activity. The Viking landings in 1976 carried the exploration of Mars forward to a high level of scientific and technological achievement, thereby setting the stage for the next step of detailed study. Analyses of meteorites and the lunar rock samples returned by Apollo continue to be highly productive, producing new insights into the early history of the inner solar system and thus leading to a revision of our previous theoretical concepts. The Pioneer Venus mission is continuing to carry the study of the Earth's nearest planetary neighbor and closest planetary analog beyond the reconnaissance stage to the point where we have now obtained a basic characterization of Venus' thick, massive atmosphere, as well as fundamental data about the formation of the planet.

The exploration of the giant outer planets began more recently. The Pioneer-10 and -11 missions to Jupiter in 1973 and 1974 were followed by the Voyager-1 and -2 spacecraft encounters in 1979. Voyager-1 then encountered Saturn in November 1980, and Voyager-2 in August 1981. The Voyager data on these planets, their satellites, and their rings have revolutionized our concepts about the formation and evolution of the solar system. Voyager-2 encountered Uranus in January 1986 and has provided our first look at this giant outer planet. Its trajectory is now carrying it to an encounter with the planet Neptune in August 1989. The Pioneer-10 and 11 and Voyager-1 spacecraft are on trajectories heading out of the solar system, as they continue to return scientific data about the outer reaches of the solar system.

Galileo will be launched on a Shuttle/Inertial Upper Stage (IUS) combination in October 1989 on a trajectory using gravity assists at Venus and Earth. The comprehensive science payload will extend our knowledge of Jupiter and its system of satellites well beyond the profound discoveries of the Voyager and Pioneer missions. During twenty-two months of operation in the Jovian system, Galileo will inject an instrumented probe into Jupiter's atmosphere to make direct analyses, while the orbiter will have the capability to make as many as ten close encounters with the Galilean satellites.

Ulysses is a joint NASA and European Space Agency (ESA) activity. The mission will carry a package of experiments to investigate the Sun at high solar latitudes that cannot be studied from the Earth's orbit Ulysses will be launched in October 1990 using the Shuttle and IUS/PAM-S launch stages.

Magellan will provide global maps of the cloud-shrouded surface of Venus, including its land forms and geological features. Using a synthetic aperture radar to penetrate the planet's opaque atmosphere, Magellan will achieve a resolution sufficient to identify small-scale features and to address fundamental questions about the origin and evolution of the planet. Magellan will also obtain altimetry and gravity data to accurately determine the planet's gravity field as well as internal stresses and density variations so that the evolutionary history of Venus can be compared with that of the Earth. Magellan is scheduled for launch in April 1989 from the Shuttle with an IUS.

Mars Observer will follow up on the earlier discoveries of Mars by Mariner 9 and Viking and will emphasize the geologic and climatic evolution of this complex planet. The mission will utilize a modified Earth-orbiting spacecraft, thereby benefiting from previously developed technology. Mars Observer will be launched in September 1992, using the Titan III/TOS launch stages.

In FY 1990, development will begin on the Comet Rendezvous Asteroid Flyby (CRAF) and Cassini (the Saturn Orbiter/Titan Probe) missions for launches in August 1995 and April 1996, respectively. Both missions will provide new understanding on the origin of the solar system and may provide new clues to the origin of life as well.

Beginning in late 1985, we entered an exciting new phase of exploration by making our first close-up studies of the solar system's mysterious small bodies -- comets and asteroids. These objects may represent unaltered original solar system material, preserved from the geological and chemical changes that have taken place in small planetary bodies. By sampling and studying comets and asteroids, we can begin to make vigorous inquiries into the origin of the solar system itself. These efforts began with the encounter of Comet Giacobini-Zinner by the International Comet Explorer (ICE) spacecraft in September 1985 and continued through our involvement with the 1986 encounters and observations of Comet Halley by U.S. and foreign spacecraft and by intensive studies of the comet from ground-based observatories coordinated through the International Halley Watch. Continued observations, studies of existing data and the archival of these data sets are ongoing.

Research and analysis activities will continue to maximize the scientific return from current missions and from such Earth-based activities as lunar sample and meteorite analysis, telescope observations, theoretical and laboratory studies, and instrument definition. This program strives for interdisciplinary coordination among various research groups and for the wide dissemination of scientific results. A close association is also maintained between the research programs and planning activities to define the scientific rationale and technology needed for future missions. The program also supports the growing involvement of U.S. scientists as participants on foreign-sponsored missions.

BASIS OF FY 1990 FUNDING REOUIREMENT

GALILEO DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Spacecraft.............................	31,377	25,100	34,880	6,200
Experiments............................	9,078	10,100	13,670	3,300
Ground operations......................	11.445	26.100	24.850	7.900
Total................................	51,900	61.300	73.400	17.400
Mission operations and data analysis.....	(--)	(--)	(--)	(39,200)
Space transportation system operations...	(31,200)	(83,900)	(85,500)	(--)

OBJECTIVES AND STATUS

The objective of the Galileo program is to conduct a comprehensive exploration of Jupiter, its atmosphere, magnetosphere, and satellites through the use of both remote sensing by an orbiter and in-situ measurements by an atmospheric probe. The scientific objectives of the mission are based on recommendations by the National Academy of Sciences to provide continuity, balance, and orderly progression of the exploration of the solar system.

The orbiter and probe will be launched together in October 1989 as a combined payload using a Shuttle/Inertial Upper Stage (IUS) combination on an initial trajectory toward Venus, followed by two Earth swingbys. The three gravitational assists will provide the energy required for a trajectory to Jupiter not otherwise obtainable with this launch vehicle. When the orbiter arrives at Jupiter it will provide remote sensing of the probe entry site and provide the link for relaying the probe data back to Earth. Twenty-two months of orbital operations will follow during which Jupiter's dynamic magnetosphere and two major satellites will be extensively mapped. During this time ten close flybys of Jupiter's four major satellites are targeted.

The Galileo flight system will be powered by two general purpose heat-source Radioisotope Thermoelectric Generators (RTG) developed by the Department of Energy. The orbiter will carry approximately 100 kg of scientific instruments and the probe will carry approximately 25 kg of scientific instruments. During

FY 1989, the spacecraft system test will be completed prior to shipment to Kennedy Space Center for integration with the IUS and Shuttle. Mission operations software development and testing will also continue in preparation for launch and post-launch operations.

CHANGES FROM FY 1989 BUDGET ESTIMATE

FY 1989 funding has been increased by $12.1 million in order to complete the extensive hardware and software modifications required to reconfigure the spacecraft for the Venus-Earth-Earth Gravitational-Assist trajectory. In addition, replacement of several electronic parts in selected subsystems is necessary and will be accomplished in parallel with ongoing spacecraft testing and integration activities.

BASIS OF FY 1990 ESTIMATE

FY 1990 funds will provide for completion of integration of the spacecraft with the IUS and Shuttle in preparation for launch in October 1989 and post-launch characterization of the spacecraft.

BASIS OF FY 1990 FUNDING REOUIREMENT

MAGELLAN DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Spacecraft..............................	43,395	14,300	23,430	--
Experiments.............................	17,017	5,400	5,880	--
Ground operations.......................	12,588	14,200	13,790	--
Total.................................	73,000	33,900	43,100	--
Mission operations and data analysis.....	(--)	(17,100)	(17,100)	(37,800)
Space transportation system operations...	(49,900)	(51,600)	(52,600)	(--)

OBJECTIVES AND STATUS

The objective of the Magellan mission is to address fundamental questions regarding the origin and evolution of Venus through global radar imagery of the planet. Magellan will also obtain altimetry and gravity data to accurately determine the planet's topography and gravity field as well as internal stresses and density variations. The detailed surface morphology of Venus will be analyzed to compare the evolutionary history of Venus with that of the Earth.

The Magellan spacecraft will carry a single major scientific instrument, a synthetic aperture radar, which will be used to obtain high resolution images of the planetary surface as well as altimetric data. Gravity data will be obtained by processing radio signals from the spacecraft. Spacecraft development has made extensive use of existing designs, technology, and residual hardware. For example, the spacecraft uses an existing bus structure, large antenna, and propulsion components from the Voyager program.

In April 1989, the Magellan spacecraft will be launched by the Shuttle/Inertial Upper Stage (IUS) on a trajectory to Venus. Arriving at Venus in August 1990, the spacecraft will map a major portion of the planet over a 243 day period (one Venus year) with a ground resolution of about 150 meters. During FY 1989, both the spacecraft and the radar sensor were shipped to the Kennedy Space Center (KSC), where they are being assembled into the spacecraft flight configuration and completing final testing. Subsequently, the spacecraft will be integrated with the IUS and the Shuttle in preparation for launch in April 1989.

CHANGES FROM FY 1989 BUDGET ESTIMATE

In FY 1989, funding has been increased by $9.2 million in order to complete final integration and test activities, which had been previously scheduled to be conducted prior to final shipment to KSC. Technical problems involving defective electronic parts have required additional rework and testing and were instrumental in delaying integration and test activities.

BASIS OF FY 1990 FUNDING REOUIREMENT

ULYSSES DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Spacecraft..............................	3,811	2,800	4,230	5,600
Experiments.............................	2,688	5,600	3,885	3,500
Ground operations.......................	1,301	1,900	2,185	5,400
Total...........................	7,800	10,300	10,300	14,500
Space transportation system operations...	(12,500)	(32,300)	(32,900)	(90,100)

OBJECTIVES AND STATUS

Ulysses is a joint mission of NASA and the European Space Agency (ESA). ESA is providing the spacecraft and some scientific instrumentation. The U.S. is providing the remaining scientific instrumentation, the launch vehicle and support, tracking support, and the Radioisotope Thermoelectric Generator (RTG). The mission is designed to obtain the first view of the Sun above and below the plane in which the planets orbit the Sun. The mission will study the relationship between the Sun and its magnetic field and particle emissions (solar wind and cosmic rays) as a function of solar latitude, to provide a better understanding of solar activity on the Earth's weather and climate.

Ulysses was restructured in FY 1981 from a two-spacecraft mission--one provided by the United States and one provided by ESA--to a single ESA spacecraft mission. However, the United States' participation in the program remains substantial. NASA is responsible for five of the nine principal investigator instruments, and three of the four European investigations have U.S. co-investigators.

The Ulysses launch is planned for October 1990, using the Shuttle and IUS/PAM-S launch stages. During 1989, support to ESA is continuing to make the spacecraft compatible with the new upper stage configuration. Launch approval activities involving the RTG, and support for retesting the spacecraft and the science instruments are also continuing.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Although overall funding remains unchanged, some reallocation was required in order to support Radioisotope Thermoelectric Generator (RTG) launch approval activities.

BASIS OF FY 1990 ESTIMATE

FY 1990 funding will support launch approval activities for the RTGs in preparation for launch in October 1990. Periodic testing of the science instruments will also continue.

BASIS OF FY 1990 FUNDING REOUIREMENT

MARS OBSERVER DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Spacecraft.............................	26,084	39,400	60,605	61,000
Experiments............................	24,842	56,700	36,095	30,900
Ground operations......................	2.974	6.100	5.500	8.600
Total................................	53.900	102.200	102.200	100.500
Space transportation system operations....	(--)	(5,000)	(5,000)	(44,700)

OBJECTIVES AND STATUS

The Mars Observer mission is the first in a series of planetary observer missions utilizing a lower cost approach to inner solar system exploration. This approach, which was recommended by NASA's Solar System Exploration Committee, starts with a well-defined and focused set of science objectives and uses modified production-line Earth-orbital spacecraft and instruments with previous space flight heritage. The objectives of the Mars Observer mission are to extend and complement the data acquired by the Mariner and Viking missions by mapping the global surface composition, atmospheric structure and circulation, topography, figure, gravity and magnetic fields of Mars to determine the location of volatile reservoirs and observe their interaction with the Martian environment over all four seasons of the Martian year.

Mars Observer will be launched in September 1992 on a Titan III with a Transfer Orbit Stage (TOS). The spacecraft will be inserted into a near-polar Martian orbit in 1993, from which it will carry out geochemical, geophysical, and climatological mapping of the planet over a period of approximately one Martian year, which is about two Earth-years.

FY 1989 funding is providing for completion of detailed design and initial fabrication of the instrument hardware and for continuation of system design of the overall mission. Detail design of the spacecraft, and parts and subassembly procurements will continue.

CHANGES FROM FY 1989 BUDGET ESTIMATE

FY 1989 funding has been reallocated in accordance with recently negotiated spacecraft system development requirements based on the September 1992 launch date.

BASIS OF FY 1990 ESTIMATE

FY 1990 funding will support the completion of spacecraft and instrument final designs. Initial hardware fabrication for both the spacecraft and instruments will also begin.

BASIS OF FY 1990 FUNDING REQUIREMENT

COMET RENDEZVOUS ASTEROID FLYBY (CRAF)/CASSINI DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Spacecraft............................	--	--	--	19,800
Experiments............................	--	--	--	8,100
Ground operations......................	--	--	--	2,100
Total................................	--	--	--	30,000

OBJECTIVES AND STATUS

During the 1970's, our Nation established scientific and technological leadership in scientific exploration of the outer solar system. The CRAF/Cassini program will extend our nation's presence in important ways during this critical period in solar system science. CRAF will be launched in August 1995, fly closely past the asteroid Hamburga in 1998, and rendezvous and with the Comet Kopff in 2000 for two years of intensive study. During this period, CRAF will deliver a penetrator to study, for the first time, the interior composition of a comet nucleus. Cassini will be launched in April 1996, fly past the asteroid Maja in 1997, gain gravity-assist velocity from Jupiter in the year 2000 while observing this planet, and arrive at Saturn in 2002 for four years of study of the Saturnian system. After achieving an orbit around Saturn, Cassini will eject a probe through the atmosphere of Saturn's moon Titan, measure atmospheric composition, and gain the first images of Titan's surface. The orbiting spacecraft will use radar to map most of Titan's surface.

The CRAF/Cassini program, building upon the discoveries made by the Pioneers and Voyagers spacecraft, will provide unprecedented information on the origin and evolution of our solar system and will help tell how the necessary building blocks for the chemical evolution of life are formed elsewhere in the universe. CRAF/Cassini targets (comet, Titan, Saturn system) have a common origin in the outer solar system. The icy conditions on all the small bodies preserve a record of different stages and processes that occurred during solar system formation and evolution. CRAF will provide the first long-term study of a comet, its active nucleus, and the nature and behavior of its ejected gases. It will enable direct analysis of the best-preserved primordial solar system material, possibly including interstellar matter. Thus it may be possible to assess organic molecules present at the beginning of the solar system and their potential contributions to the origin of life. Cassini will provide intensive, long-term observations of Saturn's atmosphere, rings, magnetosphere, and moons. The Cassini probe will conduct direct physical and chemical analyses of Titan's organically rich, nitrogen atmosphere, which is a possible model for the pre-biotic stage of Earth's atmosphere. Thus through the joint study of origins with CRAF and early processes with Cassini, using data from each in support of the other, the CRAF/Cassini program will help establish the early evolutionary processes of our solar system.

Both CRAF and Cassini will use virtually identical Mariner Mark II spacecraft and hence common design, fabrication, test, and integration team elements. This commonality significantly reduces the overall cost of design and development. With contributions from the Department of Defense and NASA's Space Research and Technology program, some $100 million has been invested in preproject definition of the Mariner Mark II spacecraft system and in demonstrating required advanced technologies. Science instruments for CRAF have been tentatively selected, and mission design issues for both missions are well understood. Therefore, NASA is confident of technical readiness to proceed.

The CRAF/Cassini program has strong components of international cooperation. The Federal Republic of Germany has agreed to provide the spacecraft propulsion system and one science instrument for CRAF and may do the same for Cassini. The European Space Agency (ESA) has selected the Cassini probe as its major new science program for this year at an estimated total cost of about $200 million. Furthermore, ESA member states will contribute about $75 million worth of science instruments and scientist participation. These contributions are tentative, however, pending approval of CRAF/Cassini for a FY 1990 new start.

BASIS OF FY 1990 ESTIMATES

FY 1990 funding is required to initiate development and long lead procurement activities of the CRAF and Cassini spacecraft in order to achieve an August 1995 launch to the comet Kopff and an April 1996 launch to Saturn. A selection of the tentative science instrument payload for the CRAF mission has been made and development will proceed in FY 1990. Science instrument development will also be initiated for Cassini investigations selected through the NASA Announcement of Opportunity process planned for December 1989.

BASIS OF FY 1990 FUNDING REOUIREMENT

MISSION OPERATIONS AND DATA ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Galilee operations.....................	--	--	--	39,200
Magellan operations....................	--	17,100	17,100	37,800
Voyager extended mission.................	2,308	3,300	2,300	--
Pioneer programs........................	7,894	9,300	8,300	9,800
Voyager/Neptune mission..................	22,312	40,300	40,124	9,300
Voyager interstellar mission.............	--	--	--	15,000
Planetary flight support.................	41,278	42,700	42.876	44.300
Total................................	73.792	112.700	110.700	155,400

OBJECTIVES AND STATUS

The objectives of the mission operations and data analysis activities are in-flight operation of planetary spacecraft and the analysis of data from these missions, Currently, two major classes of planetary spacecraft are operating--the Pioneer and the Voyager spacecraft. The planetary flight support activities are those associated with the design and development of planetary flight operation systems, and other activities that support the mission control, tracking, telemetry, and command functions for all planetary spacecraft.

The two Voyager spacecraft are now exploring the outer solar system on trajectories that will take them into interstellar space. Voyager 1 continues to provide data on the interplanetary medium in that distant part of the solar system. In January 1986, Voyager 2 made a close flyby of the planet Uranus, the first time this planet has ever been visited by a spacecraft. During this flyby, it made detailed observations of the planet, its rings, and moons. Upon completion of the Uranus encounter, the spacecraft began its path to the planet Neptune, where, in August 1989, it will provide us with our first close look at this distant planet.

After the Neptune encounter, Voyager 2, designated as the Voyager Interstellar Mission (VIM), will be on a trajectory which will extend exploration beyond the outer limits of the Sun's sphere of influence. The principal objectives of the VIM are to investigate and characterize the outer Solar System particles and fields environment and interstellar media, to provide data on the location of the heliopause in conjunction with Pioneer-10 and -11, and to continue the successful Voyager program of ultraviolet astronomy.

Pioneers 10 and 11 continue to explore the outermost solar system. Pioneer 10 will soon enter the unexplored region beyond Pluto where the Sun's influence is secondary to those of true interstellar space. These spacecraft will continue the search for gravitational evidence of a tenth planet. Pioneers 6-9 are still collecting information on the interplanetary magnetic field and solar wind as they orbit the Sun. The Pioneer Venus orbiter continues to obtain data on Venus' atmosphere and magnetosphere and its interaction with the solar wind. In late 1985, the spacecraft's spin axis was adjusted to allow ultraviolet observations of Comet Halley. Pioneer Venus was the only spacecraft able to observe the Comet at its closest approach to the Sun, thus providing critical enhancements to the data gathered by foreign spacecraft.

The planetary flight support activities include the procurement, operation and maintenance of mission operations and general purpose scientific and engineering computing capabilities at the Jet Propulsion Laboratory (JPL). In addition, the activity supports the development of the Space Flight Operations Center (SFOC) at JPL. This facility will be a versatile, cost-effective means for carrying out multimission data acquisition, telemetry, image processing, and for commanding of planetary and orbital spacecraft.

FY 1989 funding is providing support for the Voyager and Pioneer operations, for analysis of scientific data returned by these missions, and for the extension of the Voyager 2 mission to a 1989 encounter with the planet Neptune. Activities are also continuing in multimission support development and software designs for activities. FY 1989 funding will also support initial operations for the Magellan mission, which will be launched in April 1989.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The net decrease of $2.0 million reflects a portion of the $10 million general reduction directed by Congress. Some Pioneer and Voyager data analysis activities will be deferred in order to accommodate the reduction.

BASIS OF FY 1990 ESTIMATE

FY 1990 funding is required for the continued operation and data analysis activities in support of the Pioneer and Magellan missions as well as for Voyager on its interstellar trajectory. Operations activities are beginning for the Galileo mission, which will be launched in October 1989. Development activities will also continue on the Space Flight Operations Center (SFOC) at the Jet Propulsion Laboratory.

BASIS OF FY 1990 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Supporting research and technology.......	45,531	50,500	46,250	61,300
Advanced programs.......................	15,095	26,600	24,700	12,300
Mars data analysis......................	3,687	4,500	4,750	4,500
Halley's comet co-investigations and watch.............................	2.995	2.000	1.200	1.000
Total...................................	67.308	83.600	76.900	79.100

OBJECTIVES AND STATUS

The research and analysis program consists of four elements required to: (1) assure that data and samples returned from flight missions are fully exploited; (2) undertake complementary laboratory and theoretical efforts; (3) define science rationale and develop required technology to undertake future planetary missions; and (4) coordinate an International Halley's Comet Watch program.

The supporting research and technology activity includes planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, and U.S. scientist participation on foreign missions.

The planetary astronomy activity includes all observations made by ground-based telescopes of solar system bodies, excluding the Sun. Emphasis is on the outermost planets, comets and asteroids. Observations are made at a wide range of wavelengths from ultraviolet to radio. The rate of new discoveries continues to be high, and the data acquired is used both for basic research in support of planetary program objectives and for direct support of specific flight missions. The planetary astronomy funding also provides for the continued operation of the Infrared Telescope Facility in Hawaii. The planetary atmospheres activity includes data analysis, laboratory, and theoretical efforts. The properties of other planetary atmospheres are amenable to measurement with planetary spacecraft and can aid us in better understanding our own weather and climate. Observations of the atmospheres of Venus, Jupiter and Saturn, acquired by Pioneer Venus and Voyager, have laid the basic observational groundwork for major advances in this field.

The planetary geology/geophysics activity is a broadly scoped program that includes the study of surface processes, structure, and history of solid components (including rings) of the solar system and investigation of the interior properties and processes of all solar system bodies, both solid and gaseous. This program emphasizes comparative studies to gain a fundamental understanding of the physical processes and laws which control the development and evolution cf all planetary bodies, including the Earth. In this respect, data from the Magellan mission will be of crucial importance.

The planetary materials/geochemistry activity supports an active scientific effort to determine the chemistry, mineral composition, age, physical properties and other characteristics of solid material in the solar system through the study of returned lunar samples and meteorites and through laboratory and theoretical studies of appropriate geochemical problems. Extraterrestrial dust grains, collected for analysis, continue to yield new and otherwise unobtainable information about the solar system and its early history. This program is coordinated with lunar sample and meteorite research, which is supported by other agencies such as the National Science Foundation. The operation of the Lunar Curatorial Facility is also supported by this activity.

The instrument definition activity is directed toward ensuring maximum scientific return from future missions by the definition and development of state-of-the-art scientific instrumentation, which are optimized for such missions.

The support for U.S. science investigators on foreign missions currently is being provided for U.S. participation on the USSR Phobos missions.

The objective of the advanced program activity is to provide planning and preparation for the systematic exploration of the solar system on a scientifically and technically sound basis. Prospective planetary missions are identified and defined through long-range studies; the technological and fiscal feasibility is evaluated, and the scientific merit is determined through interaction with the scientific community. The strategy for future solar system exploration has been developed by the Solar System Exploration Committee (SSEC), an advisory group, which has recommended a comprehensive program of missions to the inner and outer solar system. The Mars Data Analysis program continues to support analysis of data obtained by Viking and earlier missions so that we are scientifically prepared for the next phase of Mars exploration. It also supports the establishment of a Planetary Data System (PDS) which will permit the archiving of these and all other data products in a manner which will promote and facilitate their use.

The International Halley's Comet Watch program is part of an international program of cooperative astronomical observations of Halley's Comet. During 1986 and 1987, support was provided to nearly three dozen U.S. co-investigators on the European Space Agency's (ESA) Giotto mission, and to conducting complementary remote sensing investigations carried out with ground-based telescopes, aircraft, rockets, and distant spacecraft. Concurrently, an observation program called the International Halley's Comet

Watch, coordinated by the United States, conducted world-wide scientific observations of the Comet Halley. The objectives of the Watch are: (1) to coordinate scientific observations of Comet Halley through its 1985-1986 apparition; (2) to promote the use of standardized instrumentation and observing techniques; (3) to help ensure that data is properly documented and archived; and (4) to receive and distribute data to participating scientists. Activities in FY 1988 were directed toward analyzing and archiving data. These activities will continue in 1989 at a reduced level of support.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The net decrease of $6.7 million reflects a reduction of $8.0 million as part of a $10 million general reduction directed by Congress. This is offset by the addition of $1.3 million for the Mars Balloon Relay experiment study and design for inclusion on the Mars Observer spacecraft.

BASIS OF FY 1990 ESTIMATE

During FY 1990, research efforts will continue in the areas of planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, Mars data analysis, and in the development of required technology to undertake future missions. Ground telescope observations will provide data complementary to that obtained from the flight missions, with emphasis on the outermost planets, comets and asteroids. Beginning in FY 1990, funding will also support the upgrading and modernization of ground-based laboratory instrumentation in order to reduce maintenance costs and down time and to improve capabilities. Initial efforts will be directed towards upgrading the Arecibo Radar facility. A variety of efforts will be pursued to improve our understanding of planetary atmospheres, including laboratory studies of reactions in deep planetary and tenuous cometary atmospheres. Geology/geophysics research will be directed at specific problems in understanding the various processes that have shaped planetary surfaces, as well as geological analyses and a cartography effort based on the Galilean, Saturnian and Uranian satellite imaging data acquired by Voyager.

Analysis of lunar samples, meteorites, and extraterrestrial dust particles will be continued in FY 1990 to determine their chemical and physical properties and thereby derive their origin and evolutionary history. Instrument definition activities will continue to support development of new state-of-the-art instruments with emphasis on those supporting a future mission to Saturn and its moon Titan and for a Cosmic Dust Collection Facility planned as an attached payload for the Space Station. The Mars Data Analysis Program will support continued analysis of Mars data in preparation for new Mars missions, and for continued development of the Planetary Data System to archive all planetary data for enhanced accessibility for all users. Within Advanced Programs, advanced technology development for potential future missions will also be continued.

The FY 1990 Halley's Comet Watch funding is required to support completion of the analysis and archival of data acquired by the Halley's Comet Watch program.

During FY 1990, research will be initiated to study origins of solar systems. This activity will support theoretical and experimental research by planetary scientists, astrophysicists and biologists. It will be coordinated through special workshops which will address a sequence of topical issues concerned with, and leading to, an understanding of the origins of planetary nebulae, evolution of those nebulae to planetary systems, the growth and history of planets so formed, and the paths of various elements and compounds (including biogenic compounds) throughout that evolution. The FY 1990 funding will also provide for continued operations of both the Infrared Telescope Facility and the Lunar Curatorial Facility.

EARTH SCIENCE
AND APPLICATIONS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — **EARTH SCIENCE AND APPLICATIONS PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Upper atmosphere research satellite mission	89,200	103,900	94,200	73,900	RD 6-5
Ocean topography experiment	74,500	97,800	83,000	72,800	RD 6-7
Scatterometer	22,600	15,800	10,600	13,800	RD 6-9
Earth science payload instrument development	27,700	45,000	46,400	66,500	RD 6-11
Mission operations and data analysis	14,700	18,500	17,600	24,800	RD 6-14
Interdisciplinary research and analysis	1,100	1,200	2,200	2,300	RD 6-16
Upper atmosphere research and analysis	32,700	34,000	31,100	38,100	RD 6-17
Ocean processes research and analysis	20,100	21,600	20,800	24,500	RD 6-19
Atmospheric dynamics/radiation research and analysis	31,400	32,800	32,000	37,400	RD 6-21
Land processes research and analysis	21,100	22,900	19,900	22,500	RD 6-24
Airborne science and applications	21,800	23,000	23,000	19,700	RD 6-26
Geodynamics	32,300	33,900	32,900	38,000	RD 6-27
Total	389,200	450,400	413,700	434,300	

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

EARTH SCIENCE AND APPLICATIONS PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Distribution of Program Amount bv Installation				
Johnson Space Center....................	78	100	100	100
Marshall Space Flight Center.............	7,237	10,700	10,700	6,800
Goddard Space Flight Center..............	168,034	220,600	203,900	216,500
Jet Propulsion Laboratory................	126,707	138,600	118,600	130,400
Ames Research Center....................	33,129	23,000	23,000	19,700
Langley Research Center..................	16,930	18,600	18,600	19,800
Stennis Space Center....................	508	500	500	500
Headquarters............................	36.577	38.300	38.300	40.500
Total................................	389.200	450.400	413.700	434.300

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS

EARTH SCIENCE AND APPLICATIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION

The goals of the Earth Science and Applications program are to improve our understanding of the processes in the atmosphere, oceans, land surface and interior of the Earth and advance our knowledge of the interactions among these environments. The program will provide space observations of parameters involved in these processes and will extend the national capabilities to predict environmental phenomena, both short and long term, and their interaction with human activities. Because many of these phenomena are global or regional, they can be most effectively (and sometimes only) observed from space. NASA's programs include scientific research efforts plus the development of new technology for global and synoptic measurements. NASA's research satellites, Shuttle/Spacelab payload program and Airborne Science and Applications program provide a unique view of the planet Earth; its physical dynamics, and radiative and chemical processes which affect habitability and the solar-terrestrial environment.

A number of significant objectives have been established for the next decade. These include advancing our understanding of the upper atmosphere through the determination of the spatial and temporal distribution of ozone and select nitrogen, hydrogen, and chlorine species in the upper atmosphere and their sources in the lower atmosphere; characterizing the current state of the terrestrial landscape, including the biosphere and the hydrosphere; optimizing the use of space-derived measurements in understanding large scale weather patterns; advancing our knowledge of severe storms and forecasting capabilities, ocean productivity, circulation, and air-sea interactions; and improving the knowledge of seasonal climate variability leading to a long-term strategy for climate observation and prediction. Studies of the cycling of key biogeochemical elements, interactions between the biosphere and the climate system, the composition and evolution of the Earth's crust and the processes that shape the Earth's crust are essential to our understanding of the global environment.

Effective utilization of remote sensing requires a balanced set of activities including: analytical modeling and simulation; laboratory research of fundamental processes; development of instrumentation, flight of the instruments on the Space Shuttle, research satellites and airborne platforms; collection of in situ ancillary or validation data; and, scientific analysis of data. The approach is to develop a technological capability with a strong scientific base and then collect appropriate data through remote and in situ means, which will address specific program objectives.

The geodynamics research objectives include determination of the movements and deformation of the Earth's crust, the processes which drive tectonic plates, the rotational dynamics of the Earth and its interactions with the atmosphere and oceans, the Earth's gravity and magnetic fields, and the interior structure and composition of the Earth. These objectives require precise measurements of crustal movements and Earth orientation over an extended period along with accurate knowledge of the Earth's geopotential fields and their variability.

The Upper Atmospheric Research Satellite (UARS) will place a set of instruments in Earth orbit which will make comprehensive measurements of the stratosphere, providing data about the Earth's upper atmosphere in spatial and temporal dimensions which are presently unattainable. Instrument deliveries are scheduled during FY 1989 with integration into the observatory occurring during FY 1990, consistent with the planned launch in late FY 1991.

Design and development activities are being continued in FY 1990 on the NASA Scatterometer (NSCAT), which will acquire global ocean data for operational and research use by both military and civil users. Due to cancellation of the Navy Remote Ocean Sensing System (N-ROSS) program, the Scatterometer is currently targeted for launch aboard Japan's ADEOS mission in 1995. Instrument selection for ADEOS is expected during FY 1989.

Development of the Ocean Topography Experiment (TOPEX) will continue in FY 1990 toward a planned FY 1992 launch. The objective of TOPEX is to acquire precise observations of the surface topography of the ocean. These data, in conjunction with NSCAT, will enable the first determination of the wind forcing and ocean-current response of the global oceans. Spacecraft development efforts have begun at Fairchild and the Jet Propulsion Laboratory.

The Nimbus spacecraft continues to collect unique data which is being used in the study of long term trends of the Earth's atmosphere, oceans and polar ice, and provides near real time data. The Earth Radiation Budget Experiment (ERBE) was successfully launched in 1984 and continues to provide valuable data. NASA is also continuing to support the National Oceanic and Atmospheric Administration (NOAA) by managing the implementation of the polar orbiting NOAA and Geostationary Operational Environmental Satellites (GOES) series on a reimbursable basis.

The objectives of the Shuttle/Spacelab payload development program are to develop, test and evaluate Earth-viewing remote sensing instruments and systems to obtain data necessary to conduct basic research projects as well as provide correlative and developmental feasibility information for major free-flying spacecraft. Current instrument developments include the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS); Active Cavity Radar (ACR); Light Detection and Ranging (LIDAR); Shuttle Imaging Radar-C (SIR-C). Earth Observing System (EOS) advanced technology development studies continues. Proposals submitted in response to the EOS Announcement of Opportunity (AO) are presently under review. Definition instrument studies will be conducted based on the AO selection results. The EOS studies represents NASA's contribution to the U.S. Global Change Research program described in a separate document accompanying the FY 1990 budget entitled "Our Changing Planet: A U.S. Strategy for Global Change Research".

BASIS OF FY 1990 FUNDING REOUIREMENT

UPPER ATMOSPHERE RESEARCH SATELLITE PROGRAM

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Spacecraft.........	45,186	57,687	49,300	20,000
Experiments........	44.014	46.213	44.900	53.900
Total................................	89.200	103.900	94.200	73.900
STS Operations	(--)	(12,900)	(13,200)	(34,700)

OBJECTIVES AND STATUS

The Upper Atmosphere Research Satellite (UARS) program is the next step in conducting a comprehensive program of research, technology development and monitoring of the upper atmosphere aimed at improving basic scientific understanding. This mission, scheduled for an STS launch in FY 1991, is essential for understanding the key radiative, chemical and dynamical processes which couple together to control the composition and structure of the stratosphere. The UARS mission will provide the first integrated global measurements of: ozone concentration; chemical species that affect ozone; energy inputs; temperature; and winds in the stratosphere and mesosphere. These measurements will complement the measurements of ozone and of atmospheric parameters affecting ozone that were made on Nimbus and SAGE. The UARS program is a critical element in overall stratospheric research and monitoring efforts; it will provide the first full data set on stratospheric composition and dynamics which will be required when very difficult decisions must be made in the future regarding production of chlorofluorocarbons. The UARS mission will also contribute to the assessment of the impact of stratospheric changes on our climate and will provide the data needed for a full understanding of the stratosphere. These understandings are essential for subsequent design and implementation of a long-term stratospheric monitoring activity. A final selection of ten experiments has been made, including infrared and microwave limb sounders which require advances in cryogenics, solid-state devices and microwave antennas beyond earlier capabilities. The instrument design and development activities are underway. A Solar Backscatter Ultraviolet (SBW) instrument will be modified to fly on the Shuttle during the UARS mission and to provide correlative data. In addition, development of the central ground data handling facility, which will permit near-realtime interactive utilization of data by the twenty-one design and theoretical investigator teams, is underway.

CHANGES FROM FY 1989 BUDGET ESTIMATE

In order to provide needed funding for near-term planetary missions, $9.7 million was reduced from the UARS program, with non-critical activities being deferred to FY 1990-FY 1991.

BASIS OF FY 1990 ESTIMATE

The FY 1990 funds will provide for continuation of the development activities on the ten UARS instruments including flight hardware fabrication, instrument assembly and environmental testing and instrument integration to the spacecraft. The spacecraft development and hardware fabrication activities will continue, including completion of the spacecraft mechanical test model program and the completion of spacecraft integration and test in late 1989.

The ground data handling facility will enable a higher level of interaction among experimenters and theoreticians than has existed with past programs. Implementation of this concept requires that the system be developed on a timely parallel path with the flight hardware so that individual experiment data processing subsystems, including algorithms and the interactive data base, provide maximum interaction and effectiveness in the design and development phase of the program and are fully verified at launch time. In order to achieve this, FY 1990 funding is required to complete design and development of the ground data handling facility including hardware delivery and checkout, software preliminary and critical design reviews, science team support and science algorithm development.

BASIS OF FY 1990 FUNDING REQUIREMENT

OCEAN TOPOGRAPHY EXPERIMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Ocean topography experiment (TOPEX)	74,500	97,800	83,000	72,800

OBJECTIVES AND STATUS

The goal of the Ocean Topography Experiment (TOPEX) is to utilize satellite radar altimetry to measure the surface topography of the global oceans over a period of three years with sufficient accuracy and precision to significantly enhance our understanding of the oceans' general circulation and its mesoscale variability. The capability of satellite altimetry to address this goal was demonstrated in 1978 by NASA's Seasat program. Such information is needed to better understand how the atmosphere drives the circulation of the oceans, how the oceans in turn influence the atmosphere and ultimately, the role of the oceans in climate.

NASA and the French Space Agency (CNES) are collaborating on TOPEX in order to more fully exploit the scientific value of the data. In exchange for this scientific collaboration and the flight of a French altimeter and tracking system, CNES will launch TOPEX in FY 1992 on an Ariane launch vehicle. TOPEX is also being planned in concert with the World Ocean Circulation Experiment (WOCE), a major international oceanographic field program being planned under the auspices of the World Climate Research Program (WCRP). WOCE will combine satellite observations from TOPEX with traditional in situ observations to enable the first comprehensive determination of the three-dimensional current structure of the global oceans. When further combined with measurements from the NASA Scatterometer (NSCAT), unique measurements of the oceans' winds and the resulting response will have been obtained. During FY 1989, the joint NASA/CNES Science Team will continue to meet; the satellite contract will continue into the development phase, Critical Design Reviews (CDR's) for the satellite, sensors, and ground data system will be held, all leading to the conduct of an end-to-end system level CDR towards the end of the fiscal year.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The TOPEX reduction is the result of Congressional direction ($10 million) as well as a $4.8 million reallocation of funding to the Scatterometer program in order to preserve the Japanese ADEOS launch opportunity.

BASIS OF FY 1990 ESTIMATE

In 1990, TOPEX will continue full-scale spacecraft system development. Final arrangements are expected to be made by CNES for the French-provided Ariane launch vehicle during FY 1989; the mission design will be refined based on input from and interaction with the Science Team; and the Science Team will confirm their post-launch research and verification plans.

BASIS OF FY 1990 FUNDING REQUIREMENT

SCATTEROMETER

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Scatterometer...........................	22,600	15,800	10,600	13,800

OBJECTIVES AND STATUS

The Scatterometer will provide accurate, global measurements of ocean surface winds which will be useful for both oceanography and meteorology. In addition to providing wind field data, Scatterometer data will permit the first global study of the influence of winds on ocean circulation, provide data on the effects of the oceans on the atmosphere, and provide improved marine forecasting (winds and waves).

The feasibility of using the Scatterometer technique from space to accurately measure winds was demonstrated by Seasat in 1978. Definition studies conducted by NASA during FY 1983 and early FY 1984 resulted in the determination that the performance requirements, as stated jointly by the research community and the Navy, could be satisfied by utilizing system design concepts similar to those used on the Seasat Scatterometer. The major improvements include the addition of two antennas for improved wind direction determination and the addition of digital filtering to compensate for Earth rotational effects

The Scatterometer was planned to fly on the Navy Remote Ocean Sensing System (N-ROSS) satellite in FY 1992. The N-ROSS program was cancelled in 1988 and the Scatterometer is now targeted for the Japanese ADEOS mission planned for launch in FY 1995. The current plan is to complete the Scatterometer instrument so as to preserve the ADEOS option, and then to store it until instrument selection has been completed by the Japanese, which is expected in 1989.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The reduction of $10 million results from FY 1989 Congressional action, offset by a reallocation of $4.8 million from the TOPEX program. The FY 1989 Scatterometer budget will maintain the instrument development activities to the extent that a possible launch aboard the Japanese ADEOS mission will be preserved.

BASIS OF FY 1990 ESTIMATE

During FY 1989, the antenna contract will be completed and all six flight antennas will be delivered. The Traveling Wave Tube (TWT) contract is scheduled to be completed and the development of the other flight hardware items will be continued. The instrument Critical Design Review, which was delayed due to the N-ROSS cancellation, will be held and delivery of the second computer system for the ground data system will occur. Planned activities in FY 1990 include the continuation of flight hardware development leading to the beginning of flight unit integration and testing at the end of the fiscal year; the completion of software requirements definition, the initiation of detailed software design, both for the ground data and flight systems; conducting the Preliminary Design Review (PDR) for the mission operation system; and confirmation of the science team.

BASIS OF FY 1990 FUNDING REOUIREMENT

EARTH SCIENCE PAYLOAD INSTRUMENT DEVELOPMENT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Atmospheric payloads....................	6,700	6,900	7,100	10,100
Earth sensing payloads...................	21,000	23,600	24,800	32,200
EOS ATD.................................	(3,500)*	14,500	14.500	24.200
Total.................................	27,700	45,000	46.400	66.500

* Previously funded under Earth Science Research and Analysis.

OBJECTIVES AND STATUS

The Space Transportation System offers the unique opportunity for short-duration flights of instruments. The Earth Science and Applications program has incorporated this capability into the Shuttle/Spacelab payload development activities in these important aspects: early test, checkout and design of remote sensing instruments for long duration free-flying missions; and short-term atmospheric and environmental data gathering for basic research and analysis where long-term observations are impractical. Instrument development activities support a wide range of instrumentation - from airborne to international flights of opportunity.

The objective of the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS) experiment is to make detailed measurements of gaseous constituents (e.g., hydrogen chloride, water, ammonia, methane) in the Earth's atmosphere by using the technique of infrared absorption spectroscopy. The data will help determine the compositional structure of the upper atmosphere, including the ozone layer and its spatial variability on a global scale. The instrument was launched in 1985 on Spacelab-3 and data analysis continues. It will be reflown on the Atmospheric Laboratory for Applications and Science (ATLAS) series. The science results from the first flight of ATMOS were of exceptional value, and the basic capability of ATMOS to measure very low concentrations of trace species in the Earth's atmosphere was clearly demonstrated. In FY 1987, ATMOS commenced a ground observation program at Table Mountain Observatory which will continue until the instrument is readied for shipment to KSC for the ATLAS-1 mission.

The Measurement of Air Pollution from Satellites (MAPS) experiment is a gas-filter correlation radiometer designed to measure the levels of troposphere carbon monoxide and the extent of interhemispheric mass transport in the lower atmosphere. The instrument was flown successfully on two Shuttle flights, and data analysis continues. It is planned for four STS flights, one for each season of the year, to provide the first observations of the global seasonal variation of carbon monoxide in the Earth's atmosphere. Reflight of MAPS is also planned on the ATLAS series.

The Active Cavity Radiometer-1 (ACR-1) is designed to aid in the study of the Earth's climate and the physical behavior of the Sun. Reflights of ACR-1 on the ATLAS series are planned. Other experiments have also been selected for reflight, including some instruments which were flown on the Shuttle orbital flight tests, and Spacelabs-1 and -2.

The modification of a Total Ozone Mapping Spectrometer (TOMS) engineering model began in late 1988 to support flight readiness for a target launch in 1991 aboard a Soviet sun-synchronous polar orbiter. This mission will provide measurements on the horizontal distribution of the ozone shield through 1992.

Components of the Shuttle Imaging Radar-B (SIR-B) will be used in building the next generation Imaging Radar instrument, SIR-C. The SIR-C will use multi-polarized, dual frequency sensor technology. SIR-C is in the development phase; System Requirements Review, Antenna Preliminary Design Review and System Preliminary Design Review are complete. In October 1987, NASA signed a Memorandum of Understanding with the Federal Republic of West Germany agreeing to joint missions of SIR-C with an x-band imaging radar to be provided by a joint German/Italian project (X-SAR). Preparations.continue for commercialization of the Large Format Camera (LFC).

Advanced spectrometer technology development activities include fundamental research in remote sensing involving airborne and spaceborne imaging spectrometer instruments. The imaging spectrometer and linear array solid-state sensor research focuses on the development of such features as inherent geometric and spectral registration and programmable high spatial and spectral resolution. The critical technology development and supporting research on the Shuttle Imaging Spectrometer Experiment (SISEX) and the linear array focal plan will continue.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The net increase of $1.4 million results from an increase of $2 million to continue development of the TOMS instrument and reduction of $600 thousand from the transfer of the Imaging Spectrometric Observatory (ISO), a Space Physics Spacelab instrument, to Physics and Astronomy Payload and Instrument Development consistent with the 1988 OSSA reorganization. TOMS funding was reallocated from the Upper Atmosphere Research and Analysis budget.

BASIS OF FY 1990 ESTIMATE

FY 1990 funds will be used to support the MAPS science team activities, including data reduction, refurbishment for reflight, and upgrading of the ground service equipment. The FY 1990 funding for ATMOS is required to support the ground observation program as well as continued science team activities, data processing and analysis, and limited refurbishments. FY 1990 funding is also required to continue the Active Cavity Radiometer (ACR) data processing, science team activities, and refurbishment for reflight on future Shuttle ATLAS flights, and development of a free-flyer version of ACR.

Preliminary definition of the advanced instrumentation and data facilities associated with the future Earth Observing System (EOS) will be continued in FY 1990. The EOS is intended as a payload on the Space Station's polar platform. Instrument definition and feasibility studies will be continued along with related system engineering and payload accommodation studies. A detailed review of those proposals is currently being conducted. The EOS studies represents NASA contribution to the U.S. Global Change Research program described in a separate document accompanying the FY 1990 budget entitled "Our Changing Planet: A U.S. Strategy fro Global Change Research".

Development activities will continue on the international (U.S. and France) Light Detection and Ranging (LIDAR) airborne instrumentation following completion of critical design reviews in preparation for the integration, ground test and first flight in FY 1989 of this multi-phase user program. In this program, both NASA and the French are supplying science knowledge and hardware to demonstrate first-time detail measurements of the atmosphere to aid in forecasting. FY 1990 funding is required for continued development of SIR-C technology, and for advanced spectrometer activities including the development of the Shuttle Imaging Spectometer Experiment.

Activities will continue preparing for the TOMS launch in 1991. In addition, alternate launch opportunities will be sought for applicable payloads.

BASIS OF FY 1990 FUNDING REQUIREMENT

MISSION OPERATIONS AND DATA ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Operations for the extended mission of:				
Nimbus 7..............................	3,700	3,600	3,400	3,400
Solar mesosphere explorer (SME)........	300	100	100	--
Correlative measurement/solar backscatter ultraviolet instrument....	500	2,300	2,200	7,000
Earth radiation budget experiment extended operations..................	6,500	10,100	9,600	10,400
Shuttle imaging radar-B................	3.700	2.400	2.300	4.000
Total............................	14,700	18.500	17.600	24.800

OBJECTIVES AND STATUS

The objective of the mission operations program is to provide for the operations, data processing, validation and data analysis of missions which have completed basic operations.

Launched in 1978, the Nimbus-7 spacecraft continues to provide significant quantities of both atmosphere and solid Earth global data for multi-discipline investigations and applications. These include atmospheric dynamics and chemistry resulting in global ozone measurements that are helping to understand the complicated heat exchanges of the atmosphere-ocean system, and, for the first time, global ocean data and sea ice concentration as well as properties of both polar caps. NASA supplies this unique sea ice concentration data in near real-time to the joint U.S. Navy-NOAA Ice Center. The ocean color measurements provide the only data on open ocean and coastal area chlorophyll concentration which relates to abundance of phytoplankton, the basic element of the ocean food chain. Current studies of complete ocean basins are expanding the understanding of global productivity. Nimbus-7 operations and data reduction/validation activities will continue in FY 1990 to support the strong demand for data.

The Solar Mesosphere Explorer (SME), launched in October 1981, continues to provide solar irradiance data. SME data analysis results allow us to better understand the complex chemical processes taking place in the mesosphere through scrutiny of data measurements of ozone, atomic oxygen, nitric oxide and solar irradiance. Data results indicate greater short-term variations and magnitude than was expected of many of the mesospheric properties.

The Correlative Measurements program serves to compare and/or correct data gathered by Nimbus and other NOAA meteorological satellites. Reprocessing of data from the Solar Backscatter Ultraviolet Spectrometer (SBUV) will continue in FY 1990 as a complement to ongoing Nimbus-7 operations.

The Earth Radiation Budget Experiment (ERBE) and its component Stratospheric Aerosol and Gas Experiment (SAGE) measure temporal variations in the Earth's radiation budget and ozone gases, in order to gain basic insight into the causes of climatic fluctuations.

Design and definition studies for the Japanese Earth Resources Satellite (JERS) will continue in FY 1990. Discussions with the Japanese government regarding the possibility of direct readout of Synthetic Aperture Radar (SAR) data from this satellite at NASA's Alaska SAR Facility have been initiated.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The reduction is funding results from the deferral of some research activities to FY 1990 in order to provide funding for the high-priority planetary missions.

BASIS OF FY 1990 ESTIMATE

Operation of the Nimbus satellite and processing of the collected data will be continued as will activities to provide ground truth for a NASA-developed ozone instrument to be flown on a NOAA meteorological satellite. The Nimbus satellite continues to produce extremely valuable data on ozone concentrations which will be used to estimate the occurrence of natural and man-made variations, sea surface temperatures, aerosol measurements, and ocean productivity. Correlative ground truth activities will also be continued in FY 1990; these in situ observations are needed to verify the quality of remote observations and improve our ability to interpret them.

In addition, FY 1990 funding is required for operating the ERBS spacecraft, data processing and analysis from the total three-instrument system, and from the SAGE-I1 instrument on ERBS.

BASIS OF FY 1990 FUNDING REOUIREMENT

INTERDISCIPLINARY RESEARCH AND ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Interdisciplinary research and analysis..	1,100	1,200	2,200	2,300

OBJECTIVES AND STATUS

Interdisciplinary research activities need to be conducted to quantitatively characterize the Earth's chemical, physical, and biological processes on the land, along with the interactions between the land, the oceans, and atmosphere, which are of particular importance in assessing the impact of these phenomena on global, physical, and biogeochemical processes. Such research is essential to investigating and assessing long-term physical, chemical, and biological trends and changes in the Earth's environment. Included in the program activities are joint efforts from a variety of disciplines, including atmospheric science, climatology, biological sciences, geochemistry, and oceanography.

CHANGES FROM FY 1989 BUDGET ESTIMATE

As directed by Congress, $1 million has been added for global climate change research activities.

BASIS OF FY 1990 ESTIMATE

In FY 1990, interdisciplinary studies will be continued with emphasis on integrating discipline-specific research activities of Oceanic Processes, Atmospheric Dynamics and Radiation, Upper Atmosphere/ Troposphere Chemistry, and Land Processes into a unified program which will help increase our understanding of critical global processes. Emphasis will be placed on specific pilot studies such as those understanding the biogeochemical processes controlling the concentration of atmospheric methane, characterizing changes in properties of the land surface and their effect on climate, and understanding the role of the oceans in the global carbon cycle.

BASIS OF FY 1990 FUNDING REQUIREMENT

UPPER ATMOSPHERE RESEARCH AND ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Upper atmospheric research...............	19,800	20,600	18,900	23,100
Stratospheric processes..................	6,800	7,100	6,400	7,900
Tropospheric chemistry...................	6,100	6,300	5,800	7,100
Total................................	32,700	34,000	31,100	38,100

OBJECTIVES AND STATUS

The Upper Atmosphere Research program is a comprehensive research and technology effort designed to investigate and monitor the phenomena of the upper atmosphere and related phenomena in the lower atmosphere. It is aimed at improving our basic scientific understanding of the global atmosphere and the methods needed to assess its susceptibility to significant chemical and physical change. The program's three major thrusts are in the areas of upper atmospheric research, stratospheric processes research, and tropospheric chemistry research.

The goal of the upper atmosphere research program is to understand the physics, chemistry and transport processes in the stratosphere on a global scale, and to assess as accurately as possible the perturbations to the atmosphere caused by man's activities. In order to accomplish this, efforts are underway to: (1) improve upper atmosphere and global troposphere models, validate them, and assess their uncertainties; (2) measure important trace chemical constituents, temperature, and radiation fields throughout the atmosphere; (3) develop sensors capable of making chemical and physical measurements of the upper atmosphere and the global troposphere both directly and remotely from space; (4) assemble and maintain the existing long-term data base of stratospheric and tropospheric ozone measurements to aid in the detection of long-timescale natural variations and man-made ozone changes; (5) determine the effects of global tropospheric chemistry on the atmosphere; (6) conduct theoretical and field studies of tropospheric/stratospheric exchange; and (7) carry out laboratory kinetics and spectroscopy investigations to support these activities. A variety of in situ and remote sensing techniques are needed to meet the objectives of determining and understanding the distribution of ozone and other trace species in the atmosphere. Data sets from a limited number of satellites are now generally available to the scientific community, including a record of the global distribution of ozone extending back over a decade, and simultaneous observations of a number of trace constituents. This data is being exploited to determine if trends in the ozone amount can be detected and to understand those processes which are directly involved with these trends.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The reduction results from the transfer of $2 million to Earth Science Payloads and Instrument Development for preparation of the TOMS instrument toward a 1991 flight. The balance represents a deferral of research activities to FY 1990 in order to provide funding for the near-term planetary missions.

BASIS OF FY 1990 ESTIMATE

Recent developments in our understanding of the ozone layer have revealed a possible non-linear dependence of ozone depletion on the amount of fluorocarbon released to the atmosphere. These findings place increased urgency on the need to verify the completeness and accuracy of the theoretical stratospheric models. In FY 1990, tests of the models will be continued by means of field measurements, model calculations, and interpretation of satellite data. The development of more realistic two- and three-dimensional models will be continued. The global data sets from past and present satellites will be further analyzed in FY 1990 to aid in the understanding of large-scale atmospheric processes.

The comparison of balloon, aircraft, and ground-based measurements will be continued in FY 1990 to ensure the validity of the different techniques that have been developed and to observe chemical species in the stratosphere and troposphere to determine the exchange of gases between the lower and upper atmosphere. These balloon and aircraft measurement programs are the only way to measure many of the localized phenomena of the atmosphere; they also help to validate satellite observations. Studies of potential new instruments for use on future satellites and suborbital measurement platforms will also be conducted in FY 1990 to ensure that new technologies are put to use in improving the capability and cost efficiency of tropospheric composition and upper atmosphere measurements.

The recent observations of a depletion in the amount of ozone over Antarctica in the austral spring have attracted a great deal of attention. In order to understand the chemical and dynamic processes that are causing this phenomena, a major aircraft mission was conducted in late FY 1987 - early FY 1988 using the NASA ER-2 and DC-8. Analysis and interpretation of the results of this mission is a critical effort in FY 1989. An Arctic and/or return Antarctic mission is planned for FY 1989 based on the results of the 1987 campaign. Data analysis and interpretation of the results of this mission will continue into 1990.

BASIS OF FY 1990 FUNDING REQUIREMENT

OCEANIC PROCESSES RESEARCH AND ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Research and analysis....................	20,100	21,600	20,800	24,500

OBJECTIVES AND STATUS

The Oceanic Processes Research and Analysis (R&A) program emphasizes the development and application of spaceborne observing techniques to advance our understanding of the fundamental behavior of the oceans, as well as to assist users with the implementation of operational systems.

The Oceanic Processes R&A program is organized into three discipline areas: (1) physical; (2) biological; and (3) polar oceanography. In physical oceanography, satellite scatterometers and altimeters are used to observe surface roughness and topography, from which surface winds and ocean current response can be estimated. In biological oceanography. color scanners are used to observe chlorophyll concentration, from which primary productivity can be estimated. In polar oceanography, microwave radiometers and synthetic aperture radars are used to estimate the characteristics of sea-ice cover and the details of its motion.

The Oceanic Process R&A program operates in concert with other federal agencies (Navy, NOAA, and National Science Foundation (NSF)) and foreign countries (Canada, European, Japan), for the World Climate Research Program (WCRP). Component WCRP efforts include the Tropical Ocean/Global Atmosphere (TOGA) and World Ocean Circulation Experiments (WOCE), a Global Ocean Flux Study (GOFS) and a Program for International Polar Oceans Research (PIPOR).

CHANGES FROM FY 1989 BUDGET ESTIMATE

Some research activities have been deferred to FY 1990 in order to provide critical funding to the near-term planetary missions.

BASIS OF FY 1990 ESTIMATE

In FY 1990, the physical oceanography research activities will include continuing planning for WOCE and TOGA, as well as the development of assimilation techniques to incorporate altimeter and Scatterometer data into numerical models for use in determining the general circulation of the oceans. In biological oceanography, global ocean productivity will be assessed based on analyses of Nimbus-7 Coastal Zone Color Scanner (CZCS) data, in order to assist with the conceptual design of the Global Ocean Flux Study. In addition, implementation studies will be performed with EOSAT for potential flight of an ocean-oriented color scanner (Sea-WIFS) aboard the Landsat-6 spacecraft. In polar oceanography, emphasis will be placed on the experimental design for the Program for International Polar Oceans Research, which is planned to involve direct reception at the Alaska Synthetic Aperture Radar *(SAR)* Facility in Fairbanks of SAR data from the European Space Agency's ERS-1 (Earth Resources Satellite) and from the Japanese Earth Resources Satellite (JERS)-1 spacecraft, due for launch in 1990 and 1992, respectively.

Significant work on the NASA Ocean Data System will be performed in order to optimize its use as a scientific support facility for the ocean research community. NASA's activities are being coordinated with the Office of Naval Research, NSF, and NOAA in order to assure that appropriate computing facilities, data archives, and communication networks will be available for the utilization of spaceborne observations from missions planned within the next decade.

Advanced technology development activities will also be continued on prospective future sensors for flight aboard both the Shuttle and free-flying spacecraft.

BASIS OF FY 1990 FUNDING REQUIREMENT

ATMOSPHERIC DYNAMICS AND RADIATION RESEARCH AND ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Global-scale atmospheric processes research and analysis..................	14,200	14,800	14,500	16,900
Mesoscale atmospheric processes research and analysis.........................	8,300	8,700	8,500	9,900
Climate research and analysis............	8,900	9,300	9,000	10,600
Total................................	31,400	32,800	32,000	37,400

OBJECTIVES AND STATUS

The research and analysis activities within the Atmospheric Dynamics and Radiation program combine a core effort which is essential in order to use space technology to address problems in atmospheric science. The three main thrusts in the program are in the areas of global-scale processes, mesoscale processes and climate research.

The objectives of the global-scale research program are to improve our understanding of large-scale atmospheric behavior and to develop improved capabilities to observe the atmosphere from space. The program involves the development of advanced remote sensing instrumentation to observe the atmosphere, the development of advanced analysis techniques to better utilize existing meteorological satellite data, and development of advanced numerical models which use satellite observations to describe the state of the atmosphere both diagnostically and predictively. Recent accomplishments include the development and application of techniques which more fully utilize passive multispectral data (IR and microwave) from the NOAA operational satellites to provide global maps of a number of key atmospheric and surface parameters. The first year of a ten-year data set of these Earth science parameters has been completed and made available to the scientific community. Additionally, special attention has been devoted to developing active Lidar techniques to provide detailed profiles of atmospheric wind, temperature, pressure, and moisture data from future spaceborne platforms. Simulations of these advanced techniques indicate their increased potential in greatly improving meteorological prediction capability.

The objectives of the mesoscale processes research program are to improve our understanding of the behavior of the atmosphere on short (minutes to hours) time scales and local to regional scales (severe weather, such as tornadoes and hurricanes). Since all of the characteristic parameters of these mesoscale processes cannot be measured directly, new techniques are under study to derive the information from other observations which can be directly measured. Such an activity requires advanced data handling and analysis techniques which rely upon man-computer interactive display and manipulation. In the area of remote sensor development, initial feasibility studies of instrumentation to observe lightning from space have been completed under the guidance of a joint NASA/NOAA working group. This group continues to study the practical value of lightning mapping from geostationary orbit and the possibility of incorporating experimental lightning mapping observations on a GOES spacecraft. A Memorandum of Agreement with NOAA is being prepared to fly a research version of the lightning mapper on GOES-M.

The Climate Research Program seeks to develop a space capability for global observations of climate parameters to increase our understanding of the processes that influence climate and its predictability. In accordance with the National Climate Program priority, research in solar and Earth radiation is led by NASA. Future thrusts will be aligned with programs of solar irradiance monitoring, Earth radiation budget monitoring and analysis, stratospheric aerosols on the radiation budget, and on selected process studies which relate to monitoring of climate change. Selected process studies related to monitoring climate change are also included. The first results of the data phase of the International Satellite Cloud Climatology Project (ISCCP) have been successfully archived and two field experiments of the First ISCCP Regional Experiment (FIRE) have been completed. Data from ISCCP and FIRE are being analyzed in conjunction with the Earth Radiation Budget Experiment (ERBE) data to improve our knowledge of cloud-radiation interactions which affect our climate. In addition, measurements of the solar irradiance will continue through the repaired Solar Maximum Mission (SMM) spacecraft, Nimbus 7 and reflights of the Active Cavity Radiometer flown on Spacelab-1.

A significant research effort to develop the capability for observing rainfall from space continues. Studies of instruments, sampling requirements, algorithm development, and modeling indicate the feasibility of sensing rainfall from space for climatic purposes. Under a bilateral agreement with the Science and Technology Agency of Japan, NASA is cooperating in a joint study of a special mission to measure tropical rainfall. Studies to accommodate a rainfall measurement experiment on the Space Station have been initiated and will be continued.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Some research activities have been deferred to FY 1990 in order to provide critical funding to the near-term planetary missions.

BASIS OF FY *1990* ESTIMATE

FY 1990 funding is required for support of the Global Backscatter experiment (GLOBE). A field campaign is scheduled for GLOBE using the NASA DC-8 during FY 1990. These airborne observations and the auxiliary observations to be made from ground-based and satellite observatories will be used to determine the seasonal and geographic variations in the backscatter of laser radiation due to atmospheric aerosols. In addition to increasing our understanding of the optical properties of the atmosphere, these data are needed in the system design of the Laser Atmospheric Wind Sounder (LAWS), a facility instrument for the future Earth Observing System (EOS).

The initiative in Radiative Gas Effects is a new focus for the Climate Research program during FY 1990. In particular, plans for the detection of greenhouse effect on climate from space observations will be pursued. The plans call for: (1) the identification of the required spaceborne measurements, process studies, and modeling improvements needed for early detection of the climatic effects of changing atmospheric composition; and, (2) the development of a NASA interdisciplinary research strategy for acquiring the technology and knowledge needed for understanding the regional and global climatic implications of projected greenhouse changes.

FY 1990 funding is required to provide instruments and support for aircraft flights to study the detail of flows around thunderstorms and weather fronts, continue development and comparison of numerical models, study atmospheric scale interactions, and develop techniques to display model outputs in four-dimensions. Continued analysis of the data collected in interagency field experiments during FY 1986 and 1987 will be performed. These data include the results of the Genesis of Atlantic Lows Experiment (GALE), the Cooperative Huntsville Meteorological Experiment (COHMEX) and the First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE). In addition, experimental, theoretical, and computational work will be done to better define the capabilities and requirements for the remote measurement of rainfall. Other activities will involve continued retrieval and archiving of global International Satellite Cloud Climatology Project data sets, analysis of data from the Earth Radiation Budget Experiment and the Stratospheric Aerosol and Gas Experiment, and continued ground-based and rocket flight support for solar irradiance monitoring. Technology development of active temperature, pressure, and moisture sounders as well as basic Lidar technology development will also be continued in FY 1990. Preliminary planning, experiment design, and technology development will begin for the large, multi-agency STORM program to evaluate the research and operations potential of new meteorological remote sensors such as: the sounder on GOES-NEXT, NEXRAD, AWIPS-90, ASOS, SSM/I, AVHRR-3 and high-altitude active and passive sensors to estimate precipitation.

BASIS OF FY 1990 FUNDING REQUIREMENT

LAND PROCESSES RESEARCH AND ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Research and analysis...................	21,100	22,900	19,900	22,500

OBJECTIVES AND STATUS

Land Processes Research and Analysis concentrates on three distinct categories of land-related change processes: biogeochemical, hydrology, and geology. The broad goal of the Biogeochemical Processes program is to achieve an improved understanding of the role of terrestrial biota in processes of global significance through the use of airborne and spaceborne sensors. Specific objectives are to understand biogeochemical processes and cycles, biotic contributions to the global energy balance, and change in vegetation state and dynamics.

The goals of the Hydrology program are to use remote sensing to achieve a better understanding of the regional and global storages and fluxes of the land component of the Earth's hydrologic cycle, to investigate the role of the hydrologic cycle in regional and global biogeochemistry, and to examine the interactions between land surface processes and regional and global climate.

The goal of the Geology program element is to derive a better understanding of the Earth's geology, geologic history, and the processes that have shaped the surface of the Earth over geologic time using spaceborne sensors. Specific objectives are: to investigate the history and evolution of the continents from early formation through accretionary, depositional, tectonic, deformational, and presently active erosional processes; and, to investigate quaternary geologic history and processes in order to unravel the course of recent geomorphic, volcanic and climatic processes for a better understanding of the evolution of land surfaces and climate over the last million years. The Remote Sensing Science program is a cross cutting activity which supports the three other disciplinary program elements through theoretical modeling and field measurements of land surface properties. At this time the focus is on obtaining a firm understanding of the physical and biological factors which control the interaction of electromagnetic radiation with the Earth's surface. The aim is to develop the capability to determine surface properties with remote sensing using only a minimum reliance on empirical or statistical techniques.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Some research activities have been deferred to FY 1990 in order to provide critical funding to near-term planetary missions.

BASIS FOR FY 1990 ESTIMATE

In FY 1990 emphasis will be on investigations using multiple sensors operating in the visible, near-infrared, shortwave infrared, thermal infrared, and the microwave. Advanced airborne instruments which are prototypes for the future Earth Observing System (EOS) will be used in a variety of geologic, ecological and hydrological experiments. The theoretical basis for the use of combined sensors will be developed within the Remote Sensing Science program element. Current theoretical models will be used in the design of these experiments which will be designed to meet specific scientific goals in the other program elements.

As a part of NASA's program for the study of Global Change, there will be a series of multitemporal ecosystems studies using the airborne prototypes of EOS instruments. Vegetation is dynamic over a growing season, and remote sensing coverage at an instant in time only captures one stage of the annual cycle. Repetitive coverage of selected sites offers the opportunity to study dynamic properties of ecosystems. We plan to select a small number of sites to be scheduled €or multiple data acquisitions spanning the growing season and to encourage several investigators to conduct investigations at any one site.

Operational satellite systems will be used in conjunction with the advanced airborne sensors. Multiyear data sets from the Landsat Multispectral Scanner, the Advanced Very High Resolution Radiometer (AVHRR) and the Scanning Multifrequency Microwave Radiometer (SMMR) will be used to study global change on the decadal scale. Global data sets will be maintained using the AVHRR and the Special Sensor Microwave Imager (SSMI), which replaces the SMMR.

The International Satellite Land Surface Climatology Project's (ISLSCP) First ISLSCP Field Experiment (FIFE), will continue. Guest investigators will be supported to broaden the base of users of this comprehensive data set, and mechanisms will be established to make the data available to other investigators.

BASIS OF FY 1990 FUNDING REQUIREMENT

AIRBORNE SCIENCE AND APPLICATIONS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Airborne science and applications........	21,800	23,000	23,000	19,700

OBJECTIVES AND STATUS

This effort covers operation of two ER-2's, a C-130, and a DC-8 aircraft in order to support Earth-sensing and atmospheric research. The DC-8 was acquired to replace the CV-990 research facility, "Galileo II", which was destroyed by fire in 1985. The replacement DC-8 has undergone required upgrades and modifications and carried out initial operations in Antartica in 1987 as part of the Ozone Hole campaign. Acquisition of a second ER-2, to replace the aging U-2C's, will be completed in FY 1989. These aircraft support other major segments of the Space Science and Applications program dealing with the Earth, the oceans, and the atmosphere. They may serve as test beds for newly developed instrumentation and allow demonstration of new sensor techniques before their flight on satellites or on Shuttle/Spacelab missions. Data obtained from these aircraft are used to refine analytical algorithms, and to develop ground data handling techniques. For example, the ER-2's acquire stratospheric air samples and conduct in-situ measurements at altitude ranges above the capability of more conventional aircraft and below those of orbiting satellites. This capability is important in gaining an understanding of stratospheric transport mechanisms.

BASIS OF FY 1990 ESTIMATE

Requested FY 1990 funding will allow operation and required maintenance of all aircraft. Operations will allow continuation of such projects as the collection and analysis of stratospheric air samples, testing of newly developed instrumentation, the demonstration of new sensor concepts, the investigation of the Ozone Hole phenomena, and participation in numerous other field experiments such as First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE).

BASIS OF FY 1990 FUNDING REOUIREMENT

GEODYNAMICS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Crustal dynamics project.................	18,300	19,000	18,200	21,200
Laser network operations.................	8,800	9,200	8,800	9,600
Research and technique development.......	5.200	5.700	5.900	7,200
Total.................................	32.300	33,900	32,900	38,000

OBJECTIVES AND STATUS

The objective of the Geodynamics program is to understand the origin, evolution, and current state of the solid Earth by measuring the movement and deformation of the tectonic plates and by measuring its rotational dynamics and potential fields. Laser ranging to satellites and the moon, microwave interferometry using astronomical radio sources and transmissions from the Global Positioning Satellite System (GPS) are used to determine precise position locations. The global gravity and magnetic fields are determined from satellite observations.

Measurements over the past years have provided experimental determination of the velocities of several of the major tectonic plates. Measurements of regional deformation across the San Andreas Fault continue to indicate a relative movement of the Pacific and North American Plate of about 6 cm per year. In addition, measurements indicate that about 4 cm of this movement is occurring in Southern California. Measurements of polar motion and changes in the length of day have been correlated, to a high degree, with variations in the angular momentum and the inertial balance of the Earth's atmosphere due to high altitude winds. The Earth's rotation was found to have slowed by five milliseconds due to the El Nino effect. The Earth's rotational dynamics are also influenced by motions of the Earth's core and the oceans. Models of the Earth's gravity field, derived from Laser Geodynamics Satellite (LAGEOS-1) data have provided the first evidence of gravity field variations. These variations are believed to be caused by continued relaxation of the crust following the last ice age and have confirmed estimates of the viscosity of the Earth's mantle layer. Analysis of the magnetic field, using data from Magsat, has confirmed the diameter of the Earth's outer core and has provided new data on secular variations of the magnetic field.

The United States and a consortium of eight European and middle East countries continue measurements of crustal deformation in Greece, Turkey, and Italy. In 1988, a mobile Laser Ranging Station operated by the Federal Republic of Germany will join similar U.S. stations in deformation studies in the U.S.

Development of instrumentation and techniques for use of the DOD Global Positioning System (GPS) for rapid crustal motion measurements has continued. The geodetic techniques developed by NASA for measurement of polar motion and Earth rotation have been adopted by the International Union of Geodesy and Geophysics (IUGG) as the basis of the new International Earth Rotation Service. Within the U.S., NOAA and the U.S. Naval Observatory (USNO) have adopted Very Long Baseline Interferometry as the basis for the National Earth Orientation Service.

Studies continued to confirm the need for improved gravity and magnetic field measurements. While considerable advances have been made in modeling the gravity field, new data are needed to achieve the resolution and accuracies required for solid Earth research. Laboratory development of a supercooled gravity gradiometer are continuing, and plans are being made for a Shuttle test of this technology. Joint studies are underway with the French on a cooperative Magnolia/Magnetic Field Satellite for extensive, long-duration studies of secular and temporal changes of the main magnetic field.

CHANGES FROM FY 1990 BUDGET ESTIMATE

Some research activities have been deferred to FY 1990 in order to provide critical funding to near-term planetary missions.

BASIS OF FY 1990 ESTIMATE

In FY 1990, measurements of plate motion between North America and Europe will be continued in cooperation with countries in Europe, the Middle East, Far East, South and Central America. Measurements of the motions of the Pacific Plate will be continued in cooperation with Japan and China. Regional crustal deformation measurements in western North America will continue in cooperation with NOAA, Canada and Mexico. The Caribbean studies will be continued and include more sites along the plate boundary and on the plate itself.

LAGEOS-1 and other satellites will continue to be used for studies of plate motion. NASA systems in the U.S., Pacific, South America, and Australia will be operated in cooperation with laser systems in 12 other countries. The LAGEOS-2, a joint mission with Italy, is presently under development by Italy and will be launched by the U.S. Theoretical studies of crustal motion, internal Earth structure and composition, and the modeling and interpretation of geopotential fields will be continued in FY 1990. In addition, system studies of a second magnetic field satellite for long-term measurements of the Earth's field (Magnolia/MFE), studies of geopotential research, and laboratory development of room-temperature and cryogenic gravity gradiometer instrumentation will continue.

MATERIALS PROCESSING IN SPACE

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

MATERIALS PROCESSING IN SPACE PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
	(Thousands of Dollars)				
Research and analysis	12,900	13,600	13,600	13,000	RD 7-3
Microgravity shuttle/space station payloads	49,800	59,800	56,400	74,600	RD 7-4
Commercial microgravity R&D enhancements	--	--	5,600	5,100	RD 7-6
Total	62,700	73,400	75,600	92,700	

Distribution of Program Amount by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center	2,375	6,850	2,700	3,500
Marshall Space Flight Center	17,160	21,100	26,500	29,700
Ames Research Center	--	--	100	200
Lewis Research Center	14,425	21,450	20,800	24,300
Langley Research Center	2,460	2,600	3,900	4,200
Jet Propulsion Laboratory	19,990	13,900	14,500	19,500
Headquarters	6,290	7,500	7,100	11,300
Total	62,700	73,400	75,600	92,700

OFFICE OF SPACE SCIENCE AND APPLICATIONS — **MATERIALS PROCESSING IN SPACE PROGRAM**

PROGRAM OBJECTIVES AND JUSTIFICATION

The mission of the Microgravity Science and Applications program is to foster the development of near-Earth space as a natural resource by exploiting microgravity and other unique attributes that may be attained in an orbiting spacecraft. In this environment, we can advance knowledge about the fundamental nature of matter, increase understanding of the role of gravity in various industrial processes, and produce limited quantities of certain exotic high-value materials for specialized applications. In FY 1990, ground-based research and payload development will be concentrated in six major areas: metals and alloys, electronic materials, glasses and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena.

During FY 1990, ground-based research will support definition studies for Shuttle and Space Station experiment candidates in areas such as containerless experiments, solidification and crystal growth, and processing of biological materials. Researchers will conduct experiments in drop tubes, towers and aircraft.

The Microgravity Shuttle/Spacelab Payloads program provides a range of experimental capabilities for all participants in the Materials Processing in Space program. The payloads program currently supports a wide variety of hardware development, from unique flight experiments necessary to conduct basic research into the fundamental nature of matter to the modular, multi-user research facilities that will be the cornerstone of microgravity science and applications research on the Space Station. Experiments will be flown on Shuttle and Spacelab, as well as any appropriate commercial space facility.

BASIS OF FY 1990 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Ground-based investigations, analysis and studies..................	12,900	13,600	13,600	13,000

OBJECTIVES AND STATUS

The research and analysis activity provides the scientific foundation for all current and future projects in the Microgravity Science and Applications program. Emphasis is placed on ground-based research which is expected to evolve into space investigations with potential for future applications. This activity also supports technology development for future ground and space capabilities, and applications activities leading toward privately-funded space enterprises. Most research projects are initiated as a result of proposals from the scientific community which are extensively reviewed by peer groups prior to selection.

BASIS OF FY 1990 ESTIMATE

Ground-based research and analysis will be continued in FY 1990 in the areas of metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena. Research will be conducted to define the role of gravity-driven influences in generic processing methods. Effort will continue at the Centers for Excellence located at the Massachusetts Institute of Technology, the University of Colorado, and the University of Arizona, as well as the Microgravity Materials Science Lab at the Lewis Research Center.

BASIS OF FY 1990 FUNDING REQUIREMENT

MICROGRAVITY SHUTTLE/SPACE STATION PAYLOADS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Materials experiment operations..........	49,800	59,800	**56,400**	*74,600*

OBJECTIVES AND STATUS

The Microgravity Shuttle/Space Station payloads program provides a wide range of opportunities for experiments in microgravity science and applications. NASA currently supports the development of STS middeck, Spacelab and cargo-bay experiments. This policy maximizes the effective use of the STS by matching an experiment with the hardware location best suited to meet its scientific and technical requirements. In some cases, the payload program supports an evolutionary program of testing flight experiment concepts in the mid-deck before committing to more complex and ambitious Spacelab or cargo-bay mounted hardware.

The Materials Processing in Space program is preparing to use Space Station as a major platform for conducting microgravity research, During FY 1987, NASA received funds from Congress to begin technical definition of six major multi-user research facilities designed to take advantage of Space Station's unique capabilities. NASA's Microgravity Science and Applications Division (MSAD) has developed a strategy for orderly evolution of microgravity experiments from ground-based research to the Shuttle, and finally to Space Station. During FY 1989 and FY 1990, MSAD will continue Space Station hardware definition, as well as equipment development for both the first United States Microgravity Laboratory Spacelab mission, and any appropriate commercial space facility. In addition to the Space Station Initiative, the Materials Processing in Space program is placing increased emphasis on NASA's Physics and Chemistry Experiments (PACE) program, which uses microgravity research to challenge and improve existing scientific theory about the fundamental nature of matter. As other nations increase their ability to exploit the characteristics of near-Earth space, the "cutting edge" experiments generated by the PACE program will play an increasingly important role in assuring continued U.S. leadership in microgravity research.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $3.4 million in FY 1989 is for mission management and integration for the United States Microgravity Laboratory Spacelab series which has been transferred to Physics and Astronomy - Shuttle/Spacelab Mission Management and Integration, in accordance with the 1988 OSSA reorganization.

BASIS OF FY 1990 ESTIMATE

FY 1990 funding is required to continue basic and applied research activities using STS middeck, Spacelab and cargo-bay experiments leading to several flights over the next few years. Investigations are planned in fluid dynamics, glasses, electronic materials, biotechnology, metals and alloys, and combustion. Development will continue on a number of Physics and Chemistry Experiments (PACE) as well as several pieces of advanced equipment in the areas of electronic crystal growth, biotechnology, metals and alloys, and containerless processing.

BASIS OF FY 1990 FUNDING REOUIREMENT

COMMERCIAL MICROGRAVITY R&D ENHANCEMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Commercial microgravity R&D enhancements.	--	..	5,600	**5,100**

OBJECTIVES AND STATUS

The Commercial Microgravity R&D Enhancements budget supports several projects formerly managed by NASA's Office of Commercial Programs (OCP). It consolidates funding for two joint Office of Space Science and Applications and Office of Commercial Programs multi-user research facilities--the Metals and Alloys Solidification Apparatus and the Crystal Growth Furnace. The program also covers the cost of modifying existing microgravity research hardware to accommodate the commercial user community.

CHANGES FROM FY 1989 BUDGET ESTIMATES

This funding was transferred from Commercial Use of Space in order to consolidate all NASA sponsored microgravity research efforts within the Office of Space Science and Applications.

BASIS OF FY 1990 ESTIMATE

The FY 1990 Commercial Microgravity R&D Enhancements budget supports continued development of the Metals and Alloys Solidification Apparatus and the Crystal Growth Furnace for flight on the United States Microgravity Laboratory series, and will provide funding needed to accommodate commercial users on existing flight hardware and ground-based microgravity research facilities.

COMMUNICATIONS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

COMMUNICATIONS PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Advanced communications technology satellite (ACTS)	75,600	--	74,600	--	
Advanced communications research	13,992	10,486	11,886	12,700	RD 8-3
Search and rescue	1,300	1,350	1,350	1,300	RD 8-5
Radio science and support studies	2,586	2,900	2,900	3,100	RD 8-6
Communications data analysis	1,322	1,464	1,464	1,500	RD 8-7
Total	94,800	16,200	92,200	18,600	

Distribution of Program Amount by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Goddard Space Flight Center	7,181	2,615	3,717	3,914
Jet Propulsion Laboratory	6,187	5,590	4,220	4,642
Lewis Research Center	78,799	4,412	78,655	6,547
Johnson Space Center	--	--	100	110
Headquarters	2,633	3,583	5,508	3,387
Total	94,800	16,200	92,200	18,600

OFFICE OF SPACE SCIENCE AND APPLICATIONS **COMMUNICATIONS PROGRAM**

OBJECTIVES AND STATUS

Advanced communications research continues to provide the development of subsystem component technology required by NASA, other government agencies, and U.S. industry for advanced communications satellite systems. Special emphasis is being given to technologies with high potential for improving spectrum utilization, satellite switching, and intersatellite link technologies, since these technologies are the key to future growth of the communication satellite and terminal markets. The mobile communications technology program will complete development of critical enabling technologies needed to insure growth of a commercial mobile satellite service in the U.S.

The Search and Rescue program is an international cooperative program that demonstrates the use of satellite technology to detect and locate aircraft or vessels in distress. The United States, Canada, France, and the Soviet Union developed the system, in which Norway, the United Kingdom, Bulgaria, Sweden, Denmark, Switzerland, Brazil and India also participate.

Radio science and support studies provides the technical basis to support U.S. and NASA interests in international and domestic communications regulatory forums. Propagation studies and measurements are performed in order to understand and account for the effects of propagation in the design and specification of space communications systems. Studies to enable new satellite applications are conducted.

Communications data analysis assists other federal agencies and public sector organizations in the development of experimental satellite communications for emergency, disaster and public service applications. The main areas of work will be preparation for future optical communications experiments and operation of the Applications Technology Satellite (ATS-3), launched in 1967.

Funding has not been included for continued development of the Advanced Communications Technology Satellite (ACTS) in FY 1990. It continues to be the Administration's policy that this flight demonstration project is more appropriately and effectively undertaken by the private sector, without subsidy or possible competition by the government.

BASIS OF FY 1990 FUNDING REQUIREMENT

ADVANCED COMMUNICATIONS RESEARCH

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Advanced communications research.........	13,992	10,486	11,886	12,700

OBJECTIVES AND STATUS

The advanced communications research program emphasizes the development of high-risk technology required to maintain U.S. preeminence in the international satellite communications market, to enable new and innovative public services, and to meet the communications needs of NASA and of other government agencies This program focuses on the "interconnectivity technologies" of on-board switching, intersatellite links, and antennas, as well as advanced optical and radio frequency technologies. Advanced studies are performed to determine the future satellite communications needs of the country and to define the technology required to meet those needs. The technology is developed and tested through an advanced proof-of-concept (POC) program. The POC devices and components are then integrated into a multiple terminal, satellite communications network in a laboratory where they undergo comprehensive evaluation.

The mobile satellite communications effort, in cooperation with U.S. industry, Canada, and other government agencies, will help implement a first generation commercial system. In FY 1988, a consortium of commercial firms was formed to introduce mobile satellite communications in the U.S. The mobile satellite communications work is consistent with the objective of the communications program to develop high-risk technology, thereby insuring the progress of a U.S. mobile satellite communications industry as a commercial application of space technology. The NASA role in future mobile communications technologies research will be aimed at testing power, bandwidth and orbital-slot efficient ground segment technology, and networking techniques.

In FY 1989, work is continuing on advanced communications technologies. The optical space communications work, employing very low power lasers, will permit communications between satellites and ground terminals, satellites and low Earth-orbiting spacecraft, such as the Space Shuttle or Space Station, and between satellites and other geosynchronous orbiting satellites, such as the Tracking and Data Relay Satellite (TDRS). Technology development is also underway in the area of monolithic microwave integrated circuits (MMIC), which have significant potential for applications in multi-port spacecraft matrix switches, low noise receivers, and multibeam antenna arrays and beam-forming networks. A number of industry studies are being sponsored to assess new areas of communications technologies required for the 1990's.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The change from the FY 1989 budget estimate is due to the recovery of appropriation realignment funds held in advanced communications research for the ACTS program pending its reinstatement in FY 1989.

BASIS OF FY 1990 ESTIMATE

The Research and Analysis program will continue to support development of the technologies necessary for future space communications satellite systems, encompassing both optical and radio communications technologies.

BASIS OF FY 1990 FUNDING REQUIREMENT

SEARCH AND RESCUE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Search and rescue.......................	1,300	1,350	1,350	1,300

OBJECTIVES AND STATUS

The NASA role and budget for Search and Rescue are limited to research and development that apply NASA technologies to Search and Rescue, specifically the next generation satellite-borne Search and Rescue equipment and advanced techniques that will make possible more precise and timely location of downed aircraft and ships in distress. Other U.S. and international Search and Rescue partners are NOAA, Coast Guard, Air Force, Canada, France, the Soviet Union, Norway, the United Kingdom, Bulgaria, Sweden, Denmark, Switzerland, Brazil and India. The Search and Rescue satellite system was declared operational in July 1985. For the U.S., NOAA has responsibility for all aspects of operational Search and Rescue, while the Coast Guard and the Air Force perform the rescues. The NASA budget contains no funding for Search and Rescue operations in FY 1990.

The Search and Rescue program, developed by NASA and international partners, has demonstrated the feasibility of using satellites to improve detection and location of general aviation aircraft and marine vessels during emergencies. The system has received worldwide acclaim and has been credited with saving more than 1,100 lives to date.

In FY 1989, NASA research is being applied to the improvement of computer programs that analyze distress signals in order to locate them more precisely. Planning and development for the Search and Rescue system to be used after the last of the current NOAA satellite series will continue.

BASIS OF FY 1990 ESTIMATE

Funding in FY 1990 will continue the NASA-unique research and development role in the areas of Search and Rescue, including the next generation satellite-borne Search and Rescue equipment, future system planning, and advanced techniques. Consistent with interagency plans and commitments, the NASA budget contains no funding for Search and Rescue operations in FY 1990.

BASIS OF FY 1990 FUNDING REOUIREMENT

RADIO SCIENCE AND SUPPORT STUDIES

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Radio science and support studies........	2,586	2,900	2,900	3,100

OBJECTIVES AND STATUS

Radio science and support studies provide the technical basis for regulatory and policy development to assure the orderly growth of existing and new satellite services. Unique analytical tools are developed and used to solve problems of inter- and intrasatellite/terrestrial system interference. Emphasis is placed on orbit and spectrum utilization studies, which include the development of frequency and orbit sharing techniques and strategies, design standards, and the determination of the effect of propagation phenomena and man-made noise on performance, design, and efficient use of the geostationary satellite orbit and the radio spectrum.

During FY 1989, the radio science and support studies program will conduct propagation studies to help minimize radio signal atmospheric interference problems in space communications as well as other advanced studies to enhance U.S. utilization of space for communications satellites.

BASIS OF FY 1990 ESTIMATE

During FY 1990, studies will continue to identify systems and technologies which make efficient use of the radio frequency spectrum and geostationary-satellite orbit. These studies will provide the technical basis to support standards development and regulatory decisions for space communications at the national and international levels. Propagation studies and measurements will also be carried out to fill the voids in data needed for design of new satellite applications for fixed communications, mobile communications, sound broadcasting, and high definition television broadcasting.

BASIS OF FY 1990 FUNDING REQUIREMENT

COMMUNICATIONS DATA ANALYSIS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Communications data analysis.............	1,322	1,464	1,464	1,500

OBJECTIVES AND STATUS

The objectives of communications data analysis are to support and to document a wide range of user experiments and demonstrations of the application of satellite communications. Past experiments on experimental satellites, such as the Applications Technology Satellite (ATS) series and the Communications Technology Satellite (CTS), have successfully provided users with the experience necessary to make informed decisions regarding the satellite communications functions. NASA's role to stimulate use of unique space facilities has led to wider application of commercial satellites that better meet the needs of potential users.

The main emphasis of communications data analysis in FY 1989 will be experiment definition for the optical communications program. Optical communications in space will employ very low power lasers to transmit information, much like current terrestrial fiber optics techniques. The advantages of optical space communications will be high data rates that will be needed for future Earth orbital satellite links, deep space to Earth orbital links, and Earth orbital to ground links.

Communications data analysis will continue to support Applications Technology Satellite (ATS) satellite, ATS-3, used by several government agencies and universities.

BASIS OF FY 1990 ESTIMATE

Experiment definition and data analysis for optical communications analysis will continue in FY 1990, as will communications data analysis support of ATS-3.

INFORMATION
SYSTEMS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

INFORMATION SYSTEMS PROGRAM

UMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Data systems	9,600	11,400	9,600	18,400
Information systems	11.200	10.900	10.300	15.700
Total	20,800	22.300	19,900	34,100
Distribution of Program Amount bv Installation				
Goddard Space Flight Center	14,554	14,233	12,917	18,736
Jet Propulsion Laboratory	4,280	4,346	3,057	3,863
Ames Research Center	968	724	2,231	6,254
Marshall Space Flight Center	--	--	--	3,700
Stennis Space Center	115	--	--	--
Headquarters	883	2.997	1.695	1.947
Total	20.800	22.300	19,900	34,100

OBJECTIVES AND STATUS

The information systems program applies advanced computer and information systems technology to support the OSSA science program. This includes data management, scientific computing, networking, and other science information needs. The program provides on-going support to the OSSA research community through the NASA Space and Earth Sciences Computing Center (NSESCC) for super-computing resources in support of modeling and simulation efforts, and the National Space Data Center (NSSDC) for archival and distribution of data acquired from spaceflight experiments and observations.

The data systems element develops and applies advanced capabilities for managing, distributing, and analyzing data and information. This includes development of generic tools and capabilities to enhance the science productivity derived from data acquired from space flight observations and experiments.

The data systems element also incorporates the OSSA computer communications for science network activity. The computer communications for science network will extend scientists' access to space data and computational resources and simplify communications and collaboration among NASA's space science and applications communities. Through FY 1988, the NASA science networks were funded as part of the program support communications network. In FY 1989, the network is funded by OSSA science missions and disciplines. Beginning in FY 1990, computer communications for science network is an element of the data systems budget.

Included in information systems is a new emphasis on science data management and archival to provide the OSSA research community with a faster, more reliable system to assimilate, archive, and distribute data. With the return of the Shuttle to operational status, a six-fold increase in data holdings is expected, resulting from missions like Cosmic Background Explorer, Roentgen Satellite, Gamma Ray Observatory, International Solar Terrestrial Program, the Upper Atmospheric Research Satellite, and Spacelab missions. OSSA researchers will benefit from automated retrieval of off-line data from large archives, implementation of a master directory for location of distributed data sets by researchers, catalog inter-operability for common searches across distributed databases, delivery of data on advanced media as requested by users, and utilization of data exchange standards to facilitate automated assimilation of data by user applications. The augmentation will build on the information systems program to emphasize standards, to evolve a unified but distributed system for managing data and information, and to evaluate changing technology options in a system framework.

During FY 1989, the information systems program will emphasize planning and preparation for the return to flight status of the OSSA program and the unprecedented volume of new data expected. Implementation of data catalogs and data networks are part of an effort to maintain the efficiency of the OSSA research community. In addition, existing data archives and computing facilities will be maintained.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The change from the FY 1989 budget estimate is due to Congressional action on the FY 1989 budget

BASIS OF FY 1990 ESTIMATE

The FY 1990 information systems program will continue emphasis on the application of computer science technologies to support the work of the NASA science disciplines. Funding is included for continued operation of the NSESCC and NSSDC. The information systems program will continue to develop common software to support ongoing research in the space and Earth sciences. An invigorated data management and data archival program will begin to support flight projects and science research disciplines. In FY 1990 the funds required for science network communications are consolidated in the data systems program. These requirements were previously funded in the individual space science and applications missions and disciplines, and account for an increase of $7.5 million to the Information Systems budget.

COMMERCIAL
PROGRAMS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1990 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR COMMERCIAL PROGRAMS

Commercial Programs	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Technology utilization..................	19,000	19,100	16,500	22,700	RD 10-1
Commercial use of space.................	29.700	38,800	28,200	38.300	RD 11-1
Total................................	48.700	57.900	44.700	61.000	

TECHNOLOGY
UTILIZATION

RESEARCH **AND DEVELOPMENT**

FISCAL YEAR **1990 ESTIMATES**

BUDGET SUMMARY

OFFICE OF COMMERCIAL PROGRAMS — **TECHNOLOGY UTILIZATION PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Civil systems..........................	1,300	--	2,300	3,000	RD 10-4
Product development....................	1,400	2,100	1,800	2,400	RD 10-4
Acquisition, dissemination and network operations....................	4,700	5,400	4,800	5,800	RD 10-4
Program development, evaluation and coordination..........................	2,600	1,500	1,500	1,700	RD 10-5
Technology applications..................	7,000	7,300	3,800	6,800	RD 10-5
Industrial outreach.....................	2.000	2.800	2,300	3.000	RD 10-5
Total.................................	19.000	19.100	16.500	22,700	

Distribution of Program Amount by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center....................	2,002	500	534	885
Kennedy Space Center....................	517	670	640	682
Marshall Space Flight Center.............	646	665	185	704
Stennis Space Center....................	1,071	865	1,120	1,231
Goddard Space Flight Center..............	1,300	1,300	940	1,720
Jet Propulsion Laboratory................	1,070	1,055	955	1,135
Ames Research Center....................	615	500	500	600
Langley Research Center..................	781	680	661	1,359
Lewis Research Center...................	365	380	533	575
Headquarters............................	10.633	12.485	10.432	13.809
Total.................................	19.000	19.100	16.500	22,700

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 BUDGET ESTIMATES

OFFICE OF COMMERCIAL PROGRAMS | TECHNOLOGY UTILIZATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION

The NASA Technology Utilization program is designed to strengthen the national economy and industrial productivity through the transfer and application of aerospace technology resulting from NASA's R&D programs. To accomplish this objective, NASA has established and operates a number of technology transfer mechanisms to provide timely access of useful technologies to the private and public sectors of the economy. Almost every part of U.S. industry is affected by the technology transfer process, especially in such areas as automation, electronics, materials, and productivity. In the public sector, medicine, rehabilitation, transportation and safety are areas in which aerospace technologies have been especially beneficial. The specific objectives of the program are:

- To accelerate and facilitate the application of new technology into the commercial sector, thus shortening the time between the generation of advanced aeronautics and space technologies and their effective use in the economy;

- To encourage multiple secondary uses of NASA technology in industry, education, and government, where a wide spectrum of technological problems and needs exist;

- To develop applications of NASA's aerospace technology, including its unique facilities, to priority nonaerospace needs of the Nation.

OBJECTIVES AND STATUS

The Technology Utilization program promotes the transfer of technology developed in NASA's R&D programs to the public and private sectors of the U.S. economy. A network of Industrial Applications Centers, Technology Counselors, and NASA installation Technology Utilization Officers form the core of the Agency's technology transfer efforts. Technologies developed for the Nation's aerospace program are reused or reengineered to provide new products and processes in the areas of transportation, energy, medicine, public safety, and consumer goods. The goals of the program are to broaden and accelerate the technology transfer process to realize additional dividends on the national investment in aerospace research and to ensure that the United States maintains its competitive position in the international marketplace.

Activities in FY 1990 will include:

- Improving the capability of the Technology Utilization Offices at the NASA Field Centers to increase the level of technology transfer activities. Implementation has been completed of a microcomputer-based system to more effectively store data and facilitate timely access to new technologies developed in NASA's R&D programs. This network, the Technology Utilization Network System (TUNS) will link the NASA TU field center offices, the NASA Software Repository, Computer Software Management and Information Center (COSMIC), the Scientific and Technical Information Facility (STIF) and the Industrial Applications Centers together to provide a quicker distribution of new technologies than has previously been possible. The system of identification of new technologies developed in NASA's R&D programs is the beginning step in the technology transfer process. The number of applications engineering projects will be increased to demonstrate the application of that technology to solving identified problems in a wide variety of areas.

- Promoting awareness of NASA's Technology Utilization program and resources available to the public and private sectors through a broad array of program materials, seminars and conferences. Industrial outreach will be expanded by efforts to identify and reach additional non-aerospace users of NASA's technologies.

- Expanding the nationwide technology transfer network to continue the development of cooperative efforts with the Federal Laboratory Consortium, state-sponsored business and technical assistance center, and Small Business Development Centers. These linkages enable the Technology Utilization program to keep pace with growing industrial demand for information and technology transfer services generated by its industrial outreach activities.

- Continuing the planning and implementation of the AdaNET program, AdaNET is a program to transfer existing and emerging Ada software and other software engineering technology from the federal government to the private sector through mechanisms such as information sharing and repository services and networks. NASA, the Department of Defense, and the Department of Commerce are participating in this program.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The distribution of funds was adjusted to include funding for the AdaNET project under the Civil Systems program ($2.3 million) and to accommodate a Congressional reduction ($2.6 million).

BASIS FOR FY 1990 ESTIMATE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Civil systems..........................	1,300	--	2,300	3,000

In FY 1990 Civil Systems will fund AdaNET is a program to transfer existing and emerging Ada software and other software engineering technology from the federal government to the private sector through mechanisms such as information sharing and repository services and networks. NASA, the Department of Defense, and the Department of Commerce, are participating in this program.

Product development......................	1,400	2,100	1,800	2,400

Based on the increasing response to Tech Briefs and expanding Industrial Applications Centers network, increases in new technology identification and reporting are anticipated in FY 1990. These resources will provide for evaluation and packaging of these technologies for publication thereby stimulating industrial interest and participation in NASA's Technology Utilization and Commercial Use of Space programs.

Acquisition, dissemination and network operations....................	4,700	5,400	4,800	5,800

In FY 1990, NASA plans continued strengthening of the Technology Counselor network at its field installations to provide for expanded identification of NASA technical capabilities and expertise. This capability and expertise is necessary for matching and cross-correlating NASA technology with industry needs specified by NASA Industrial Applications Centers. To facilitate timely and efficient interaction between Technology Counselors, Industrial Applications Centers and other organizations in NASA a Technology Utilization Network System communications system is planned for functional utilization in FY 1990. Expansion of this capability, increased effective communication, and data storage and retrieval systems will greatly enhance the overall capability of the network to coordinate technology transfer activities, and respond to user needs efficiently with minimum overlap and duplication of effort. Moreover, the system will enable technology transfer managers to maintain appropriate controls over the process to insure overall program effectiveness and management accountability.

BASIS FOR FY 1990 ESTIMATE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Program development, evaluation and coordination..........................	2,600	1,500	1,500	1,700

With an expanded role in industrial outreach, additional emphasis will be required in the development of program goals and objectives in terms of long range plans for NASA Technology Utilization (TU). Focused efforts on assessing potential participants in U.S. industry, preparing information guidelines to support cooperative relationships throughout the NASA technology transfer network, as well as satisfying anticipated increased demand for TU publications and responses to increased number of program inquiries are among the many management planning and support requirements. Specific actions are also planned for FY 1990 to strengthen program development, evaluation and coordination on an internal as well as external basis to support the national technology transfer network and emerging commercial use of space outreach efforts.

Technology applications..................	700	7,300	3,800	6,800

In FY 1990, a broadening of application team responsibilities is anticipated to assist NASA Industrial Applications Centers in bringing together industrial client problems with existing aerospace technologies leading to project definition and industry-driven cooperative projects. This effort will result in increased tangible and meaningful applications of aerospace technology in the private sector, thus enhancing the productivity and competitive posture of U.S. industry.

Industrial outreach......................	200	2,800	2,300	3,000

In FY 1990, NASA will utilize its existing dissemination center network to contact and acquaint U.S. industrial firms with opportunities to actively interact and participate with NASA in technology transfer and space commercialization. Such contacts are envisioned on a face-to-face basis, with appropriate follow-up including seminars, and conferences and workshops to explore more detailed characteristics of the "opportunities" for interaction. The NASA Industrial Applications Centers are in a unique position to serve as NASA's surrogate in aligning U.S. industrial interests in space commercialization as well as opportunities for terrestrial commercialization of advanced technologies derived from NASA's R&D programs. The technological needs of industry, would benefit from this synergistic approach designed to bring engineering resources of both in closer proximity. Successful technology transfer occurs most frequently in an environment where knowledge is shared easily and advantages through cooperative endeavors are explained and understood. It is this role that the NASA dissemination center network can readily fulfill.

COMMERCIAL
USE OF SPACE

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF COMMERCIAL PROGRAMS — **COMMERCIAL USE OF SPACE**

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Commercial applications and enhancements.	25,200	36,600	25,100	34,400	RD 11-4
Commercial development support...........	4.500	2.200	3.100	3.900	RD 11-5
Total................................	29.700	38.800	28.200	38,300	

Distribution of Program Amount by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center....................	600	100	3,500	1,700
Kennedy Space Center....................	519	460	316	661
Marshall Space Flight Center.............	4,207	19,700	1,594	1,900
Stennis Space Center....................	4,254	300	2,600	5,500
Goddard Space Flight Center..............	150	200	140	300
Jet Propulsion Laboratory................	--	--	--	--
Ames Research Center....................	540	450	400	550
Langley Research Center..................	434	1,095	--	1,095
Lewis Research Center...................	2,210	1,025	350	1,000
Headquarters............................	16.786	15.470	19.300	25.594
Total...........................	29.700	38,800	28,200	38,300

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

OFFICE OF COMMERCIAL PROGRAMS **COMMERCIAL USE OF SPACE PROGRAM**

PROGRAM OBJECTIVES AND JUSTIFICATION

The goal of the Commercial Use of Space program is to establish a national focus in support of opportunities for the expansion of U.S. private sector investment and involvement in civil space activities. The specific objectives of the program are to:

- Establish close working relations with the private sector and academia to encourage investment in space technology and the use of the in situ attributes of space--vacuum, microgravity, temperature and radiation for commercial purposes.

- Facilitate private sector space activities through improved access to available NASA capabilities and the development of new high technology space ventures and markets.

- Encourage an increase in private sector investment in the commercial use of space independent of NASA funding.

- Develop and implement commercial space policy NASA-wide.

OBJECTIVES AND STATUS

NASA's goal of expanding opportunities for U.S. private sector investment and involvement in civil space and space-related activities is pursued through a variety of interrelated programs. Through cooperative agreements such as Joint Endeavor Agreements **(JEA's)** and through our support to the Centers for the Commercial Development of Space (CCDS) we will increase the amount of space-related research conducted by the private sector, the number and type of NASA and private sector facilities available for space use, and the private sector awareness of the opportunity to use NASA's terrestrial and space-based facilities for commercial research.

Resources will be made available to obtain flight support experimentation hardware required by industrial researchers. This may include across-the-bay carriers, such as Materials Science Laboratories, as well as middeck augmentation racks or derivatives thereof, and the possible leasing of private sector hardware developed to exploit commercial research and development in space. The use of ground-based research facilities, aircraft and sounding rockets for commercial experimentation will be given emphasis in order to provide limited access to the microgravity environment for appropriate commercial experiments.

In order to maintain momentum in commercial use of space activities and to encourage an increase in private sector investment in space, NASA will continue to develop methods to facilitate private sector agreements and commitments to develop commercial opportunities in space. The development of agreements for the use of the Shuttle external tanks and private sector use of U.S. launch facilities reflect this effort. The use of Space System Development Agreements (SSDA's) will continue.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The current estimate for FY 1989 has decreased by a net of $10.6 million. $5.6 million has been transferred to the Office of Space Science and Applications Materials Processing in Space Program to support commercial microgravity research and development enhancements. As a result of FY 1989 Congressional actions, Commercial Applications and Enhancements has been reduced $5.0 million. This reduction will result in deferral of existing programs including planned work in remote sensing and space flight support. Finally, $0.9 million has been transferred from Commercial Enhancements to Commercial Development Support for ongoing activities.

BASIS FOR FY 1990 ESTIMATE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Commercial applications and enhancements.	25,200	36,600	25,100	34,400

In FY 1990, NASA will continue the Centers for the Commercial Development of Space (CCDS). Sixteen CCDS's have already been established in such diverse areas as space propulsion, biotechnology, materials processing, and space remote sensing. The CCDS's through space-related research conducted by the private sector and NASA, and the enhancement of private sector awareness of the availability of NASA's terrestrial and space-based facilities for potential commercial research and exploration, are a focus for the commercialization of space. Funding will be provided to increase flight readiness through projects focused to respond to industry identified requirements for hardware and flight opportunities. Continued development of space-oriented, ground-based facilities and equipment will expand the technical research data base which enables the private sector to make economic decisions to commit to space research and production. Through coordination with the private sector and the Office of Space Science and Applications, guidance will be developed and provided for the commercial microgravity research and development enhancements program.

Funding is provided for the analytical and physical integration required for Space Shuttle payloads flown under Joint Endeavor Agreements (JEA's). Direct funding is provided for reimbursable optional services which are deferred under some Space System Development Agreements (SSDA's). NASA's current SSDA's are with Spacehab, Geostar and Space Industries Partnership. In addition, alternate launch opportunities will be sought for applicable payloads.

BASIS FOR FY 1990 ESTIMATE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Commercial development support...........	4,500	2,200	3,100	3,900

Rapidly changing economic, commercial and technical circumstances continue to require ad hoc and ongoing studies by experts to provide the direction and feedback needed by the program. In FY 1990 additional emphasis will be placed on our strategic planning capability to allow us to formalize analyses and methods for implementation of an effective Commercial Space Development program and to assist in the development of agency commercial space policy. A financial analysis capability will be developed to support the analysis of potential opportunities for commercial development.

AERONAUTICS AND
SPACE TECHNOLOGY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1990 ESTIMATES

RESEARCH AND DEVELOPMENT PLAN FOR AERONAUTICS AND SPACE TECHNOLOGY

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
	(Thousands of Dollars)				
Aeronautical research and technology.....	332,900	414,200	404,200	462,800	RD 12-1
Transatmospheric research and technology.	52,500	84,400	69,400	127,000	RD 13-1
Space research and technology............	221.300	390.900	295.900	338.100	RD 14-1
Total................................	606,700	889.500	769.500	927.900	

AERONAUTICAL
RESEARCH AND
TECHNOLOGY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

AERONAUTICAL RESEARCH AND TECHNOLOGY

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Research and technology base	257,150	314,200	315,563	335,700	RD 12-5
Systems technology programs	75.750	100.000	88.637	127.100	RD 12-27
Total	332.900	414,200	404.200	462.800	

Distribution of Program Amount Bv Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Marshall Space Flight Center	1,825	4,100	1,800	3,900
Jet Propulsion Laboratory	250	300	300	300
Goddard Space Flight Center	219	200	200	200
Ames Research Center	139,099	157,900	155,400	169,200
Langley Research Center	107,988	144,300	142,400	165,000
Lewis Research Center	76,733	100,200	94,900	114,200
Headquarters	6.786	7.200	9.200	10.000
Total	332.900	414.200	404.200	462.800

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY | **AERONAUTICAL RESEARCH AND TECHNOLOGY**

PROGRAM OBJECTIVES AND JUSTIFICATION

The goal of the NASA aeronautics program is to conduct research and develop technology to strengthen U.S. leadership in civil and military aviation. This goal is supported by five comprehensive program objectives: (1) emphasize emerging technologies with potential for major advances in capacity and performance; (2) maintain NASA's laboratory strength by repairing and modernizing critical aging national facilities, providing advanced scientific computational capabilities and enhancing staff technical excellence; (3) ensure timely transfer of research results to the U.S. aeronautics community through reports, conferences, workshops and cooperative research programs with industry; (4) ensure strong university involvement to broaden the nation's base of technical expertise and innovation; and (5) provide technical expertise and facility support to the Department of Defense (DoD), other government agencies, and U.S. industry for major aeronautical programs. The program is based on a strong commitment to revitalize American competitiveness in the world aviation marketplace, enhance the safety and capacity of the national airspace system, and assure U.S. superiority for national security.

In order to continue to meet the international challenge in aeronautics, the FY 1990 estimate reflects the need to address critical barriers and strengthen generic technology development in selected high payoff areas that are vital to our long-term leadership in aviation. NASA's FY 1990 aeronautics program is focused on achieving the objectives established in the report, "National Aeronautical R&D Goals: Technology for America's Future," by the Office of Science and Technology Policy (OSTP), and by its sequel report, "Agenda for Achievement."

CHANGES FROM FY 1989 BUDGET ESTIMATE

The aeronautics research and technology program was reduced by $10.0 million as a result of Congressional action on the FY 1989 budget request. This reduction is reflected in the advanced composites program under materials and structures systems technology.

Within the research and technology base program, a number of realignments have been made as a result of implementing new charging algorithms for program support requirements in the scientific and technical automatic data processing and facilities areas. This change, which allocates costs to benefiting programs, was an outgrowth of the appropriation realignment activity of last year.

The research and technology base program reflects an increase of $1.4 million, which is primarily the result of a realignment of funding from the numerical aerodynamic simulation program required for priority program requirements in the research and technology base.

BASIS OF FY 1990 ESTIMATE

The FY 1990 research and technology program is committed to addressing the critical issues associated with the U.S. air transportation system, to enhancing American competitiveness in the international marketplace, and preserving the country's preeminence in aviation for national security. Technologies are being pursued which, when fully implemented, could offer major advances in vehicle performance and capabilities and which could provide substantial positive impact on U.S. competitiveness. Research efforts have been expanded in high payoff areas associated with a broad range of future vehicle applications including high-performance aircraft, and high-speed transport aircraft. The demands for NASA's unique wind tunnels are continuing to increase with the emergence of new civil and military aircraft programs. In order to ensure wind tunnel availability to meet these demands, a major five-year revitalization program was initiated to modernize NASA's major wind tunnels for productive use well into the next century. This revitalization program is entering its second year in FY 1990.

A brief summary of the key elements of the research and technology base and systems technology programs follows:

Fluid and thermal physics research will continue to focus on developing faster and more efficient algorithms for numerical simulation of aerothermodynamic phenomena.' In applied aerodynamics, the augmented research program in FY 1990 will emphasize induced drag reduction and turbulent drag reduction. Propulsion and Dower research will continue to emphasize improved fundamental understanding of stationary and rotating turbomachinery flowfields through development of advanced computational analysis methods and their applications at the component and subsystem level. Materials and structures research will continue to develop advanced materials and innovative structural concepts aimed at reducing aircraft weight and cost. Research in information sciences will continue to investigate concurrent processing architectures and algorithms for application to increasingly complex aerospace computational problems and will emphasize advanced software engineering for complex, highly reliable applications. Controls and guidance research will continue to provide a technology foundation in advanced systems for application to future aerospace vehicles, with emphasis on guidance and control for highly agile aircraft. Human factors research will continue development of methodologies required for safe and effective crew/cockpit interfaces with particular emphasis on highly automated aircraft operating in the future national airspace system. Flight systems research will be augmented to increase emphasis on high angle-of-attack technologies through simulation, wind tunnel tests, and flight evaluation. Systems analysis studies will continue to focus on defining the research and technology needs for advanced high-speed transport aircraft, high-speed rotorcraft, and supersonic short takeoff and vertical landing fighter aircraft. In materials and structures systems technology, advanced composite materials research will continue in high-temperature materials while expanding its focus on application of composites to primary aircraft structures. Rotorcraft systems technology research will continue the FY 1989 effort in noise prediction, code validation, and envelope expansion of the XV-15 tiltrotor with advanced technology blades. In high-performance aircraft systems technology, flight system research will start a new focus on high-speed flight, addressing environmental issues such as ozone depletion, airport noise, and sonic boom. Advanced propulsion systems technology will focus primarily on high-speed turboprops with specific emphasis on improved understanding, modeling, and code validation of flowfields, structural response, noise characteristics, and installation effects. The numerical aerodynamic simulation capability will be enhanced with the acquisition of the third high-speed processor.

BASIS OF FY 1990 FUNDING REOUIREMENTS

RESEARCH AND TECHNOLOGY BASE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Fluid and thermal physics research and technology...........................	23,718	26,500	32,800	33,500	RD 12-6
Applied aerodynamics research and technology...........................	56,868	64,300	68,463	73,800	RD 12-8
Propulsion and power research and technology...........................	46,662	70,100	70,100	71,500	RD 12-11
Materials and structures research and technology...........................	38,453	40,100	40,100	40,500	RD 12-14
Information sciences research and technology...........................	19,189	23,000	9,600	11,700	RD 12-16
Controls and guidance research and technology...........................	20,905	35,700	36,400	37,000	RD 12-18
Human factors research and technology....	20,494	19,700	17,700	17,800	RD 12-20
Flight systems research and technology...	25,400	28,800	30,800	39,800	RD 12-22
Systems analysis.......................	5,461	6,000	9,600	10,100	RD 12-24
Total...............................	257,150	314,200	315,563	335,700	

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Fluid and thermal physics research and technology............................	23,718	26,500	32,800	33,500

OBJECTIVES AND STATUS

Fluid and thermal physics research is performed to advance the understanding of fundamental fluid mechanics phenomena and to derive efficient aerodynamic prediction tools. The research includes efforts in fluid physics, computational fluid dynamics (CFD), CFD code validation, and viscous flow studies. The latter area includes laminar stability analysis, boundary layer transition, and analytical turbulence. CFD research is performed for the prediction and simulation of complex fluid flows over aircraft. The validation of prediction and simulation methods is accomplished by means of a coordinated experimental test program. This activity also provides improved insight into the fundamentals of flow physics, as well as the detailed flow measurements required for verification of the computations. Viscous flow research is conducted with emphasis on developing specific devices and design techniques to reduce overall aircraft drag.

Numerous advanced solution algorithms have been generated for complex viscous flows, and innovative gridding techniques developed to resolve the added geometrical complexity of realistic three-dimensional configurations. These new algorithms and gridding techniques were tested for three-dimensional geometries at transonic and supersonic speeds. To assess the accuracy and reliability of these new techniques and codes, both computational studies and experimental verification activities are in progress. Significant advances have been made in the enduring problem of understanding, predicting, and modeling the onset and structure of turbulence. The Center for Turbulence Research completed a highly successful first year of operation with coordinated efforts in theoretical computational and experimental turbulence physics. Experiments were identified to be conducted to generate the data for turbulence modeling and code validation. Drag reduction flow research efforts have focused on laminar flow control, natural laminar flow concepts, and turbulent skin friction drag reduction. The development of surface geometry modifiers included research to extend proven concepts such as riblets and large eddy breakup devices to supersonic speeds. These passive friction reduction techniques have also been applied to the control of flow separation associated with shock wave/boundary layer interaction.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The fluid and thermal physics research and technology program has been increased by $6.3 million. This includes a research and technology base realignment of $7.0 million of program support costs which are associated with the Ames Research Center central computer facility and Dryden Flight Research Facility data analysis facility, and $0.5 million associate with the simulation facilities at Ames Research Center, offset by a reduction of $1.2 million which was realigned to the applied aerodynamics program in order to support priority configuration aerodynamics research.

BASIS OF FY 1990 ESTIMATE

In FY 1990 CFD research will be directed toward development of faster and more efficient numerical algorithms to facilitate full Navier-Stokes solutions including flows with large wall curvatures and jet ejection. Improved methods will be derived for numerical simulation of aerothermodynamic flow phenomena associated with hypersonic cruise and maneuver vehicles including real-,gas chemistry. Enhanced computational capabilities will be sought through development and use of advanced computer architectures and expert system concepts. Sophisticated, generic Reynolds stress turbulence models exhibiting greater flow realism and wider applicability will be generated. Research will be initiated to acquire a detailed data base for propulsive-lift flow interactions in ground effect. CFD validation investigations will produce transonic data bases necessary for validation of CFD codes simulating transports and other configurations. Increased emphasis will be provided for validating supersonic and hypersonic flow analyses.

Drag reduction research will emphasize high-speed skin friction reduction techniques. Passive and active concepts will be explored for flow control separation for drag reduction, stability improvement, and vehicle control. Fundamental flow mechanism investigations will include the study of turbulent flow coherent structures and boundary layer transition physics. Turbulent skin friction reduction devices, such as surface geometry modifiers, will be explored for the supersonic regime. Vorticity control concepts will be investigated for preventing flow separation. Hypersonic stability and boundary layer transition analyses will be performed to derive transition prediction techniques. CFD methods will be developed for slender bodies and highly swept wings characteristic of supersonic cruise configurations, including emphasis on interacting vortex flows, wing leading-edge radium effects, and variable camber devices. Emphasis will be placed on validation of transition methods for highly swept wings at supersonic speeds.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Applied aerodynamics research and technology............................	56,868	64,300	68,463	73,800

OBJECTIVES AND STATUS

The objective of applied aerodynamics research and technology is to provide new, validated technology applicable to future U.S. military and civil aircraft from subsonic to hypersonic speeds. The approach is to conduct comprehensive ground and flight experiments involving realistic vehicle configurations and key configuration components. Such work is focused on areas expected to render major gains in advanced vehicle performance. Products include new analytical and experimental methods needed in the design process and new aerodynamic concepts. This work covers the full spectrum of civil and military air vehicles, including both rotary-wing and fixed-wing concepts, and also includes the area of aeroacoustics.

Configuration aerodynamics research identifies and analyzes innovative aerodynamic concepts. This program uses wind tunnel, water tunnel, and flight experiments to complement analytical aerodynamic developments for complex flows over aircraft components and configurations. Wing/airfoil optimization techniques were extended from subsonic and transonic speeds to the supersonic regime. Panel aerodynamic methods are tailored to analyze flows over an F-16 aircraft with tip missiles and under-the-wing fuel tanks. Advanced computational algorithms are developed for exploring vortex interactions. Cellular formation studies are underway for the derivation of separated flow control techniques.

Subsonic aerodynamic research emphasizes research on induced drag reduction and separated flow control to reduce aircraft drag and improve aircraft stability and control. Novel approaches to achieving lower induced drag are being investigated in the form of unconventional wing planform (e.g., crescent) and sheared wingtip shapes. New nonplanar wing theories and wind tunnel tests show that these new wing shapes can yield efficiencies higher than originally thought possible, based on classical planar wing theory. Flight tests are also conducted to support industry applications of spin-resistance technology to new aircraft designs.

Significant advancements have been made in recent years in the development of codes for application to the low-disk-loading rotors of conventional (e.g., helicopter and tiltrotor) and advanced rotorcraft. While the methodologies will continue to evolve, one of the most important needs for the near term is the experimental verification/validation of these methodologies. Preparations for major experimental activities have been completed, and these experiments will be the focus of the rotorcraft program over the next few years. These activities include both flight test and wind tunnel test programs, with primary emphasis on the investigation and measurement of unsteady airloads and high-speed performance. In addition, significant activity over the next few years will be devoted to the support of new military rotorcraft programs.

The high-performance (fighter/attack) vehicle research program is focused in three key technology areas: (1) short takeoff and vertical landing (STOVL), (2) high angle-of-attack maneuverability, and (3) supersonic cruise and maneuver. In the STOVL arena, research is directed toward new powered-lift concepts for hovering; methods to predict the complex flow surrounding a hovering vehicle, especially near the ground; and investigation of flight dynamics of transition between hover and forward flight. Studies have been completed to define the most promising STOVL vehicle concepts, and the key technologies needed are being pursued. In the area of high angle of attack, both new experimental and analytical methods are being developed for the prediction and control of the separated and vortex flows which will allow advanced, superior U.S. vehicles to push beyond the traditional stall barrier by virtue of increased stability and control. In the supersonic cruise arena, new nonlinear prediction and design methods for advanced airfoils and wing planforms are being developed to improve cruise efficiency and maneuverability of advanced fighters.

Research is performed to derive advanced techniques and instrumentation for more accurate and efficient testing, both in wind tunnels and in flight, to validate the analytical methods. An adaptive wall test section has been developed and installed in the 0.3-meter transonic cryogenic wind tunnel. Wall interference-free data are being taken on advanced airfoil test sections. Instrumentation research has emphasized high-speed flow sensing to support U.S. initiatives in supersonic and hypersonic vehicles. Concepts to be investigated include infrared boundary layer transition visualization, micro-encapsulated liquid crystal methods for advanced flow visualization, and laser fluorescence for hypersonic flow sensing. Also, the development of laser velocimetry to obtain high-response measurements in supersonic shock flows is being pursued.

In the area of aeroacoustics research, work continues to determine acoustic and structural fatigue loads of supersonic heated flows (i.e., jet exhausts). Particular emphasis has been placed on determining flight effects and the effects that these high-frequency loads have on airframe and structural design for advanced aircraft.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The applied aerodynamics research and technology program was increased by $4.2 million and consists of realignments of $1.2 million from the numerical aerodynamic simulation program to cover program support requirements at Ames Research Center, $1.2 million for configuration aerodynamics research from the fluid and thermal physics program, and $1.8 million of program support costs from information sciences research and technology associated with the Ames Research Center central computer facility.

BASIS OF FY 1990 ESTIMATE

The research program in FY 1990 will emphasize induced drag reduction and turbulent drag reduction. Induced-drag research activities will focus on wing-tip and trailing-edge geometry modifications to reduce drag due to lift. A supersonic flight test of riblets as a means to reduce turbulent skin friction will be conducted. Flight research to determine the stability and control characteristics of sheared wing tips will be initiated. Flight tests to evaluate the handling qualities of natural laminar flow wings will be completed. Transition mode and sensor instrumentation will be evaluated in a flight research program.

Research efforts will be made to acquire a test-validated sophisticated technique for predicting three-dimensional wing flow separation. An advanced vortical flow analysis method to predict wing and wake flows at high angle-of-attack attitudes will be sought. Research will be performed to acquire an improved understanding of wing/body vortical flows to include insights into vortex production and breakdown phenomena. Three-dimensional viscous flow interaction phenomena will be explored through analytical and experimental approaches.

Several major full-scale rotorcraft experimental programs will be continued. One such activity is a joint program between NASA, the U.S. Army, and industry to conduct an experimental flight investigation with a highly instrumented UH-60 Black Hawk helicopter. The performance, noise, and vibration characteristics of tiltrotor aircraft, in hover and in forward flight, will be investigated.

High-performance research in the STOVL arena will include the evaluation of advanced configurations developed under the U.S./United Kingdom program and the identification of technologies to be pursued, as well as the completion of a wind tunnel test of a large-scale advanced powered-lift fighter concept. High angle-of- attack research will continue development of analytical predictions of post-stall aerodynamics and comparison with wind tunnel and flight test angle-of-attack conditions. Supersonic research will extend the analytical modeling methods to include solution-adaptive grid refinements; applications to arbitrary, complex geometries; and the development of techniques to predict aerodynamic control surface effectiveness and the characteristics of thrust vectoring nozzles.

Efforts will be initiated for development of real-time interferometry techniques for unsteady flows. Advanced methods will be pursued for accurately sensing and handling aerodynamic flight test data, both boundary layer and off-surface flows. Measurement techniques for time-varying turbulent velocity fields will be explored. Development of three-dimensional wind tunnel adaptive wall techniques will be investigated. Wind tunnel model magnetic suspension research will be reduced in FY 1990.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Propulsion and power research and technology............................	46,662	70,100	70,100	71,500

OBJECTIVES AND STATUS

The objective of the propulsion and power research and technology program is to provide the understanding of the governing physical phenomena occurring at the disciplinary, component, and subsystem levels that will support and stimulate future improvements in propulsion system performance capability, efficiency, reliability, and durability. Research is being conducted in a wide variety of subsystems with applications ranging from general aviation through the hypersonic aerospace plane. Ongoing disciplinary research on instrumentation, controls, internal fluid mechanics, and aerothermodynamic concepts is providing the foundation necessary for continued advancement at the component and subsystem level. These research efforts will lead to high-payoff propulsion system improvements which have historically provided a major share of aircraft performance advances and also enabled new classes of vehicles.

In the discipline areas, internal computational fluid mechanics continues to be an increasingly important tool for understanding flow phenomena and improved designs of aeropropulsion systems through the development of advanced algorithms and analysis methods for complex three-dimensional flows in inlets and nozzles, turbomachinery and chemically reacting flows, including their validation with basic experiments. A two-dimensional steady viscous reacting flow code that incorporates real-gas properties and is capable of high-speed hydrogen-air combustion solutions has been completed and distributed to industry. In 1989, the reacting flow code will be extended to three dimensions, and the initial turbulent reacting shear-layer flow data sets will be obtained for verification. In addition, a three-dimensional Navier-Stokes code will be validated for internal flow and heat transfer in inlets, ducts, and nozzles. The second area, instrumentation and control research, is aimed at developing advanced high-temperature sensors, optical nonintrusive measurement systems, and advanced engine sensors and controls for future propulsion systems. Laboratory evaluations of two nonintrusive Rayleigh scattering-based gas density and temperature measurement systems have been completed, and the most promising system will be field tested in FY 1989 to demonstrate its advantages in actual research use. A prototype fiber-optic position sensor has also successfully completed environmental testing, and the electro-optical architecture for incorporating this and other passive optical sensors in an integrated propulsion-airframe control system will be defined in FY 1989.

For subsonic transport propulsion research, the objective is to develop the fundamental technologies to improve the thermal efficiency of advanced subsonic powerplants by 20 percent. In 1989, the first year for this research activity, concept studies will be used to identify specific research needs for thermal efficiency improvement. Research will be initiated to develop a large low-speed axial turbomachinery rig which will be used to develop empirical closure models for advanced analytical methods that are an enabling technology for development of high-pressure-ratio compression systems. General aviation engine research is aimed at rotary engines with the objectives of 40 percent reduction in fuel consumption, a power density increase of 30 percent, and multifuel capability. Stratified-charge rotary engines have demonstrated multifuel capability and the goal increase in power density. Experimental verification is underway for a five percent cycle efficiency improvement achieved by eliminating wake interferences between fuel jets, as predicted by a three-dimensional model of internal air flow and fuel injection patterns.

In supersonic cruise research, the objective is to develop technology for efficient, environmentally compatible propulsion concepts for Mach 2 to 4 cruise operating conditions. During FY 1988, all hardware fabrication and facility modifications for rig testing of the supersonic throughflow fan concept were completed. Initial testing of the fan rotor will begin in late FY 1989 after facility checkout completion. The scope of research in this flight regime is also being expanded in FY 1989 to include engine cycle and configuration studies, and initiation of small-scale experiments to address two critical areas of environmental acceptability--reduction in airport noise and engine emissions. For high-performance applications, the goal is to develop propulsion systems technology for powered lift and thrust vectoring that will lead to improved aircraft short takeoff and vertical landing (STOVL) and supermaneuvering capability during flight. Principal activities during FY 1988 included small-scale model experiments on advanced inlets and nozzle concepts, and the modification, upgrading and calibration of several research facilities for improved component flowfield measurements and analysis code validation. Planned milestones for FY 1989 include the completion of test and analysis on a short diffuser inlet, an initial block-and-turn ventral nozzle experiment, and a full-scale ejector system based on mixed-cycle primary air.

The hypersonic propulsion research objective is the development of the basic understanding of high-energy fluid phenomena, dynamic models, advanced concepts, and the diagnostic and facility technologies for high-speed cruise at Mach 4 and above. Development of the shear layer combustion facility will be completed in 1989 to study the effect of combustion on the shear layer mixing process. Experimental studies will be initiated to determine the effects of contaminants, such as water vapor and nitrogen oxide, on the supersonic combustion process.

BASIS OF FY 1990 ESTIMATE

Research emphasis in internal computational fluid mechanics will be placed on advanced prediction capabilities that are three dimensional, viscous, and include reacting flow and heat transfer, where appropriate. The experimental data base from the large, low-speed centrifugal compressor will be used to determine the ability of a three-dimensional viscous turbomachinery code to model the important flow characteristics such as separated and secondary flows. A two-dimensional viscous turbomachinery code that predicts heat transfer will be extended to three-dimensional and validated using the results of the compressible flow experiment that includes detailed measurements of surface heat transfer and the flowfield with a horseshoe vortex which is typically found in turbine flow passages.

Advanced instrumentation and control research will continue to focus on the development of nonintrusive optical sensors, high-temperature electronics, and the growing need and advantages of propulsion-airframe integrated controls. With respect to research instrumentation, efforts will be applied to the development of 1800-degree-Fahrenheit static strain gages, a thin-film (30-micron) heat flux gage, and limited-view gas density measurement systems using heterodyne holographic interferometry. In the controls area, hardware for the selected electro-optical architecture will be fabricated, integrated with optical engine and airframe sensors, and the combination environmentally tested to ensure function and durability.

Subsonic transport research will include the completion of the low-speed multistage flow physics facility for turbomachinery and the acquisition of the initial viscous blade row interaction experimental data base for turbomachinery code verification and closure model development. Turbine design will begin for the warm turbine rig which will be used to develop the experimental verification data base for three-dimensional viscous turbomachinery codes that include heat transfer. General aviation engine research activities will continue to focus on advancing rotary engine technology. The structural viability of a titanium lightweight rotor for improved rotary engine power density will be determined and tests initiated. Analysis of the combustion process through advanced computer modeling will guide further improvements in combustion efficiency to enable the fuel consumption goal of 0.35 brake-specific fuel consumption.

Supersonic cruise research will continue the development of advanced propulsion concepts such as the supersonic fan and innovative turboramjet-type cycles offering improved high-speed efficiency and flight envelope expansion. Continuation of testing of the supersonic fan will include full-stage mapping (rotor plus exit stator) and use of laser anemometry measurements to define and analyze the complex flowfields. Thermal performance testing of a prototype ceramic heat exchanger will also be completed, and studies will continue with industry to define innovative components and configurations that extend the advantages of turbomachinery-based propulsion to higher Mach number capability. In the area of high-performance aircraft research, efforts will continue to concentrate on super maneuverability and STOVL technologies for future fighter aircraft. Small-scale inlet model testing at high angle of attack and analysis with more sophisticated codes will be conducted to identify critical stability issues, and the exhaust gas ingestion effects data base will be expanded to include several promising STOVL configurations through the use of a new, more flexible aircraft model and test support system.

Hypersonic propulsion activities will include fundamental experiments to provide an understanding of high-speed inlet flow physics, exhaust system flow physics and its associated flow chemistry, heat transfer experienced in internal flow systems with very high-energy flows, mixing mechanisms necessary for complete heat release, and high-speed combustion. These experiments will be guided with, and the results compared to, advanced three-dimensional flow analysis codes that have the capability to resolve separations in the flow, flow chemistry, and heat transfer rates. Successful completion of the experiments will require advanced nonintrusive research instrumentation that can resolve not only flow velocity and direction, but also density and chemistry.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Materials and structures research and technology............................	38,453	40,100	40,100	40,500

OBJECTIVES AND STATUS

The objectives of the materials and structures rese rch a d technology program are to: (1) develop and characterize advanced metallic, intermetallic, ceramic, polymer, and composite materials; (2) develop novel structural concepts and design methods to exploit the use of advanced materials in aircraft; (3) advance analytical and experimental methods for determining the behavior of aircraft structures in flight and ground environments; and (4) generate a research data base to promote improvements in performance, safety, and durability of aircraft, as well as reduce the weight and life cycle cost.

Research in materials is directed toward airframes and high-performance gas turbine engines. In airframe materials research, studies are being conducted in advanced materials for high-temperature applications including new thermoplastic polyimides and metal matrix composites, processing methods for superplastic forming of aluminum alloys, light alloys such as aluminum-lithium, and intermetallics. Engine materials research focuses on advanced metals, intermetallics, ceramics, fiber-toughened ceramics, and polymers.

Aircraft structures research is focused on developing innovative concepts for airframes and engines that are lightweight, durable, and cost-effective. Primary areas of research are advanced analytical methods to predict structural response, multidisciplinary analysis and optimization to predict aerodynamic and acoustic loads and improve design methodology, understanding fatigue and fracture mechanisms to improve reliability, and low-cost fabrication methods.

Research in aeroelasticity includes computational methods to predict flutter and performance of aircraft; control concepts to improve performance, enhance stability and reduce loads; and development and testing of advanced aircraft configurations. Activities are balanced between the needs of civilian aircraft to improve competitiveness and national defense needs for high-performance aircraft.

Primary areas of rotorcraft research are understanding and predicting main rotor aeromechanics, multiblade interactions, and response and control of noise surrounding and inside rotorcraft. Current emphasis is placed on advanced main rotor configurations, airborne and structureborne noise reduction, and the interactions of the helicopter main rotor with airframe dynamics.

Hypersonic research is directed toward lightweight material systems and structural concepts that can withstand the very high temperatures encountered during hypersonic flight.

BASIS OF FY 1990 ESTIMATE

Materials research will concentrate on advancing the understanding of the relationship between processing parameters, microstructure, and properties of metallic, intermetallic, ceramic, polymer, and composite materials, with primary emphasis on high-temperature applications. New and tougher organic matrix composites capable of long-term use up to 700 degrees Fahrenheit; reliable monolithic and whisker-toughened silicon-carbide and silicon-nitride, high-strength/ductile intermetallic aluminides; and fiber-reinforced aluminide composites will be developed. This will also require new and innovative composite fabrication methods. An understanding of fatigue, fracture, and time-dependent deformation behavior of light alloys and metal matrix composites at both elevated and cryogenic temperatures will be pursued. Multiaxial constitutive models for composites will be developed for prediction of environmental effects, high-temperature cyclic damage, and loading rate dependence.

Airframe structures research will continue to emphasize the mechanics and fundamental behavior of composite structures and innovative concepts for use of light metallic structures. Specifically, during FY 1990 methods for predicting and preventing failure modes in composite structures will be studied, including nonlinear behavior of buckled shells and complex three-dimensional structures and matrix interleaving to improve toughness of integrally stiffened structures. In support of subsonic aircraft, impact drop tests will be conducted on composite aircraft fuselage sections. Propulsion structures research will develop integrated structural/thermal tailoring methodology for high-temperature engine components and evaluate concepts for composite engine structures and advanced actively controlled bearing concepts.

Advanced analytical methods will be developed in the computational structural mechanics (CSM) program. CSM will focus advanced computational methods, including probabilistic analysis and boundary elements for the structural analysis of airframes and engines, emphasizing the solution of very large, complex problems. NASA's supercomputer facility will be used to develop solution methods for very large problems while superminicomputers and highly configurable transputers will be used to develop solution schemes for various computer architectures.

The aeroelasticity research activity will develop analytical methods to predict unsteady aircraft loading using advanced Euler methods and will develop control laws to reduce the maneuver load for a flexible actively controlled wing. The effects of damping and blade mistuning will be incorporated into the analysis of counter-rotating turboprops, and research will continue to understand the aeroelastic response of supersonic flow through turbomachinery.

Interdisciplinary research will develop efficient optimization methods for coupled aero-structural design of aircraft wings and rotorcraft main rotors. In particular, to support the rotorcraft research activity, a main rotor concept optimized to reduce dynamic loading'willbe tested in the wind tunnel.

In hypersonic research, integrated flow/thermal/structural analysis methods will be used for accurate mission loads prediction to aid the development of lightweight, efficient, and durable airframe and propulsion systems. New materials and structural concepts will be evaluated for actively cooled hot structures. Additional efforts will focus on ceramic composites, intermetallic composites, and carbon/carbon, constitutive behavior, and oxidation-resistant and thermal barrier coatings.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Information sciences research and technology............................	19,189	*23,000*	9,600	**11,700**

OBJECTIVES AND STATUS

The information sciences research and technology program will provide the fundamental capabilities to: (1) exploit advanced computer architectures to meet NASA's unique computing requirements, (2) increase the agency's ability to develop high-quality aerospace systems software, and (3) provide the advanced theory, concepts and capability to effectively use and manage aerospace information. Effective exploitation of computational modeling of physical processes, such as computational fluid dynamics (CFD), will be enabled through the development of a fundamental understanding of the relationship between physical algorithms and advanced parallel processing architectures. Research on the theoretical foundations for managing complex software systems and on the development and validation of reliable software is directed toward improving the quality and reducing the cost of complex mission-critical software.

Parallel processors offer the potential for enabling numerical simulation at affordable costs. A prototype algorithm was implemented and tested on the connection machine. Also, prototype algorithms for solving incomprehensible flows and for solving high-altitude transonic flows using particle tracing methods were implemented and tested. Evaluating performance of parallel processors is an important problem to both computer systems architects and application developers. A distributed operating system testbed was established to conduct performance evaluations on selected distributed operating system concepts developed under research grants. Performance prediction tools are being developed for the evaluation of different concurrent architectures and in the detection of bottlenecks in hardware and software. A set of metrics which can accurately measure the performance of numerical architectures was developed. The scientist's workbench, providing a vehicle for testing advanced work station concepts, incorporated graphics super work stations capable of handling three-dimensional data and animation. The hardware prototype of the space-distributed memory was brought on line and put in use for experiments, including the testing of the text-to-speech translation problem. The University of Illinois conducted a series of research tasks addressing the reliability and development of complex mission-critical software. The theoretical basis for the assessment of software redundancy was extended, specifically addressing the model of coincident errors. A nonreconfigurable, fault-tolerant operating system for verifiable integrated processor for enhanced reliability (VIPER) microprocessors was specified in the enhanced hierarchical design methodology (EHDM) proof environments.

The high-speed mainframe computer networking subsystem continues to provide NASA aeronautical researchers remote access to the agency's mainframe computers. The system supports transmission rates up to 1.5 million bits per second from NASA's geographically distributed research centers.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The information sciences research and technology program reflects a decrease of $13.4 million. This is the net effect of several adjustments, including a realignment of $10.8 million of the Ames Research Center's central computer facility program support costs to other benefiting programs within the research and technology base and a transfer of $3.6 million to systems analysis to support high-speed studies and hypersonics research, offset by an increase of $1.0 million to support university activities in computer sciences, and a realignment of $48 thousand from advanced turboprop systems to cover program support requirements.

BASIS OF FY 1990 ESTIMATE

Research on the use of novel parallel processors controlled by new algorithms for efficient numerical simulation will continue at the Research Institute for Advanced Computer Science (RIACS). Performance of special purpose CFD computers, including a systolic processor and the Navier-Stokes machine, also will be evaluated. The research will address other aerospace applications of parallel processing including computational structural dynamics and visual research. Experimentation on prototype programming environments for parallel systems and use of parallel algorithms to benchmark advanced architectures will continue. Research in sparse distributed memory, developed as a mathematical model of human long-term memory with the properties of associative recall, will continue; the theory underlying the new memory architecture will be advanced. The ultimate capability of such a memory could include computer vision and natural language. A hardware simulator will be evaluated in a number of aerospace application studies. One set of evaluations will include the study of how effectively the computer can be trained to recognize characters. A research program in networked systems to examine the interactions and underlying capabilities provided by systems of computers, experimental facilities, and humans connected by networks will be conducted. The focus is on the architecture of such distributed systems and the resulting requirements for network function and performance.

Software engineering studies will quantify the reliability gained from formal specification, software prototyping, computer-aided software engineering systems, software reuse, and formal verification. The Institute for Computer Applications in Science and Engineering will conduct research in these areas. The block grant for fundamental computer science at the Illinois Computing Laboratory for Aerospace Systems and Software at the University of Illinois will address characterization and evaluation of automated support tools for increased reliability in software specification and design, including Ada programs.

NASA will continue to support the operation of the computer networking system to provide for the effective and productive use of NASA's distributed computing resources. NASA will continue to work through the Federal Coordinating Council for Science, Engineering and Technology to coordinate national access to high-performance computers.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Controls and guidance research and technology............................	20,905	35,700	36,400	37,000

OBJECTIVES AND STATUS

The controls and guidance research and technology program will provide a technology base supporting future aircraft designs which will be capable of safer and more efficient operation and will have greatly expanded flight envelopes. The specific objectives of the controls and guidance program are: (1) to exploit emerging controls, guidance, and artificial intelligence (AI) technologies for the development of advanced automation concepts for applications, including rotorcraft nap-of-the-Earth (NOE) flight and more efficient operations within the national airspace system; (2) development of highly reliable system architectures and validation methods for flight crucial systems; (3) development of airborne wind shear detection sensors; (4) development of advanced control, guidance and display theories, concepts and analysis methods; and (5) development of new methodologies for multidisciplinary integration.

Knowledge-based control and guidance concepts have been shown to be feasible for improving system design, performance, and crew-vehicle interface. Research culminating in flight test has demonstrated reduced development time and added in-flight capability for an aircraft system redesigned using AI techniques. Analytical methods, assessment techniques, and experimental methodologies have been developed for the evaluation and validation of fault-tolerant, concurrent processing, and distributed computer systems for aircraft applications. Multiple tools and software codes are now distributed to and are in use by industry,

Three alternate technologies for in-flight detection of wind shear are currently under investigation. The recently developed wind shear hazard index has achieved status as an industry standard. Additionally, microburst models for dynamics and structures applications have also received wide industry acceptance. As high-order dynamics become more important to aircraft performance, safety and efficiency, the integration of numerous heretofore specialized disciplines has become a critical necessity. Multidisciplinary techniques for integrating controls, guidance, propulsion, structures, and cockpit systems are being pursued. Structures and controls have been integrated into a preliminary set of control laws for an active flexible wing model now being prepared for wind tunnel testing.

Advanced air traffic flow control concepts and the integration of four dimensionally equipped aircraft into the national airspace system are under study to improve the efficiency of air traffic control (ATC) operations. Both simulation and flight tests have been performed in preparation for an upcoming operational test to be conducted with the Federal Aviation Administration at a test site to be selected in the future.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The controls and guidance research and technology program has been increased by $0.7 million, which includes an increase of $1.0 million of program support costs associated with simulation facilities previously carried in the human factors program, offset by a realignment of $0.3 million to information sciences to support university activities in computer sciences.

BASIS OF FY 1990 ESTIMATE

Continued analytic and systems research in nonlinear control theory, fault-tolerant systems, wind shear modeling, and advanced display concepts will be conducted. A complementary mix of near-term applications and long-term basic research will be balanced to provide focused efforts on specific milestones, while continuing research in state-of-the-art technologies. As individual areas of aircraft design, control, and propulsion become increasingly sophisticated, once minor effects and influences from other aircraft systems begin to gain importance. As a result, multidisciplinary modeling and design techniques will be emphasized as a high potential research topic.

Increased emphasis also will be placed on in-flight demonstration and test in a number of research areas, including live ATC evaluations at Denver, system component research for automated NOE flight, in-flight evaluations of alternative wind shear detection devices, and preliminary development of AI-based controls and guidance techniques for an entire transport aircraft flight control system. These tests will greatly improve the final validation of research developments and assist in timely transfer of new technology to industry users.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Human factors research and technology	20,494	19,700	17,700	17,800

OBJECTIVES AND STATUS

The objective of the aeronautical human factors research and technology program is to provide the capability to design effective crew-cockpit interfaces and air traffic control (ATC) interfaces with the aircraft. Advanced automation technologies, along with increased traffic density, challenge human operators and their interface with diverse air and ground systems. The goal of the program is to provide human-centered technology which is safe, productive, efficient and effective for advanced commercial and military aircraft, rotorcraft, and other national aeronautical applications.

Flight management research in FY 1989 will provide new concepts for audio and visual display of potentially conflicting air traffic and recommended evasion and escape from pending collisions which is a follow-on to the earlier traffic alert and collision avoidance system (TCAS). A hybrid symbolic/neural network model has been developed and will be applied to a new pilot situation assessment and rapid decision-making aid. A prototype of a situation-adaptive crew information management system which allowed human interface with an intelligent diagnostic system was completed. Pilot acceptance tests will be completed for a three-dimensional velocity vector system which was shown on a helmet-mounted display. Simulator evaluation of wind shear adaptive guidance techniques for use in landing under severe wind shear conditions will be completed in FY 1989.

Human engineering research will lead to new physiological and behavioral workload assessment and monitoring techniques for predicting pilot performance. Tests were conducted to explore the relationship between pilots' reported level of boredom in long-haul flights and their performance as seen in physiological measurements of cortical activities. Analysis of two-person crews in long-haul, multiple time zone flights will be conducted to determine effective countermeasures to circadian desynchronosis.

Research in aviation safety/automation will provide guidelines for the design and implementation of automated systems in the cockpit. Simulation and flight experiments were performed to evaluate a final approach spacing tool for ATC personnel so they could handle increased traffic in the landing phase of flight operations. New concepts for identification and display of multiple in-flight faults were identified. An automated system for monitoring crew cockpit procedures will be evaluated in 1989.

In focused rotorcraft research, several information presentation techniques for day and night flight were developed and will undergo evaluation in FY 1989. These allowed more precise flight path control and geographical orientation. A unique set of data was compiled relating to pilot error under high-stress flight conditions associated with emergency medical evacuation.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The human factors research and technology program has been reduced by $2.0 million. This includes a realignment of $0.5 million to the information sciences research and technology program to support university activities in computer sciences and a transfer of $1.0million of program support costs associated with simulation facilities to the controls and guidance and $0.5 million to fluid and thermal physics research and technology disciplines.

BASIS OF FY 1990 ESTIMATE

Base human factors research and technology development will continue to provide methods whereby flight crew performance will be improved and human-error opportunities reduced. Among these methods will be the following: application of three-dimensional displays for visual tracking of very precise flight paths and display of position in vertical and horizontal range of multiple aircraft; tests and verification of pilot performance enhancement due to usability of in-flight, computer-based fault detection and classification techniques; guidelines for pilot procedures to allow the crew to maintain a level of awareness under levels of low workload and low task demands; and development of rotorcraft crew procedures for visual search and visual navigation under low levels of visibility and high workload conditions.

The aviation safety/automation program will enter a phase of intensive simulation testing, experimentation, proof-of-concept demonstration, and evaluation of human-centered automation. New techniques of information exchange, management, and display in cockpits and at ATC work stations which reflect various levels of automation will be tested. Guidelines and concepts developed in FY's 1988 and 1989 from the entire human factors base program will provide a technical basis for these new interfaces between humans and automated systems. Tests of these guidelines in FY 1990 will lead to intelligent, error-tolerant or error-resistant cockpits and ATC work stations which must function safely and effectively in the future automated ATC environment. Planning activities performed in FY 1989 will be completed and implemented in updated air traffic control simulation facilities at Ames Research Center and Langley Research Center so that testing may begin. Other base research in flight management, subsonic transport, and human engineering methods will feed into this program.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Flight systems research and technology...	25,400	28,800	30,800	39,800

OBJECTIVES AND STATUS

The objective of the flight systems research and technology program is to provide the necessary research and technology development for an improved and validated base of advanced technology for application by industry to future generations of the entire spectrum of aircraft. The program is organized into the following categories: (1) aviation safety; (2) flight instrumentation and test techniques; (3) fighter/attack aircraft; and (4) flight support. The activities within this program encompass advanced engineering techniques and the establishment of the feasibility of concepts to ensure rapid applications of promising new technology essential to meeting one or more of the following goals: (1) reducing aircraft accidents resulting from weather effects (heavy rain and icing); (2) improving flight efficiency, enhancing data accuracy, and enabling the acquisition of needed information; and (3) establishing a technology base for the design of future fighter aircraft with unprecedented maneuverability at high angle-of-attack (up to 90 degrees) flight conditions and vertical landing capability. Support services are provided to flight research projects using standard aircraft for chase, airspeed calibration, remotely piloted research vehicle drops, and flight crew readiness training.

The heavy rain tests using the aircraft landing dynamics facility have been completed, and the lift loss caused by heavy rain has been established for a typical airfoil section. The model helicopter rotor tests, which were conducted jointly with industry in the icing research tunnel, have been completed. Ice shape and section drag measurements have been obtained on a Twin Otter aircraft for comparison with data from the icing research tunnel. A developmental model of the airborne information management system was used in flight to measure vertical wind shear in the atmosphere. The evaluation and ranking of short takeoff and vertical landing (STOVL) propulsion concepts were completed, and the concept-specific technology development program has been defined and initiated. The baseline vortex flow characteristics have been established for the F-18 aircraft at high angle of attack by both on-surface and off-surface flow visualization. Detailed forebody and leading-edge extension (LEX) pressure distributions were also obtained for correlation with wind tunnel and computational fluid dynamics (CFD) results. Advanced CFD methods have been employed to calculate the flowfield around the forebody, LEX, and wing with excellent comparisons to the F-18 aircraft. The critical design review for the multiaxis thrust vectoring system was completed and manufacturing was initiated.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The flight systems research and technology program increase of $2.0 million is associated with the allocation of benefits of Ames Research Center's central computer facility to this discipline. These funds were realigned from the information sciences research and technology program.

BASIS OF FY 1990 ESTIMATE

The emphasis in aviation safety will continue in the areas of advanced concepts for ice protection, improvement of the ice accretion prediction codes, acquisition of additional ice accretion physics data, development of methodologies for icing scaling, improved cloud droplet instrumentation, and flight tests to validate predictive codes and icing research tunnel results. Test data acquired from the aircraft landing dynamics facility will be analyzed to assess the aerodynamic penalties associated with heavy rain.

The F-18 high angle-of-attack research vehicle will be modified with the addition of a multiaxis thrust vectoring system to enhance maneuverability and agility. Flight research, using the F-18 high angle-of-attack research vehicle (HARV), will be conducted to investigate the potential benefits and assess the aerodynamic, propulsion system, structural, and flight control system interactions resulting from multiaxis thrust vectoring at high angles of attack. Prediction methods for high angle-of-attack aerodynamics will be validated through correlation of CFD, wind tunnel, and flight results. A national symposium is scheduled in FY 1990 to report the progress in correlating CFD and flight-measured aerodynamic results. Emphasis will be placed on the accelerated development and understanding of critical integrated control technologies incorporating thrust vectoring to attain and control flight at post-stall conditions. Vortex control methods will be developed and evaluated in wind tunnel tests. In the STOVL program for FY 1990, the development of critical technologies identified in recent studies will be continued. These include analytical and experimental research in the areas of flow diverter valves and ducts, integrated flight/propulsion control systems and handling qualities, cruise and vertical landing nozzles, and ground environmental effects.

Development and flight evaluation of an advanced airborne information management system will continue. Flight tests and evaluation of a single-axis optical air data system will be conducted, and research will be initiated to develop a three-axis optical air data system suitable for use in flight.

Flight test support of flight research projects will continue using a variety of both fixed- and rotary-wing aircraft. These high-performance support vehicles will be flown as chase aircraft in support of research aircraft described under high-performance systems technology (X-29, F-18, F-15, F-16XL) and rotorcraft systems technology (XV-15, tiltrotor). Also included is specialized training for critical personnel, as well as maintenance of flight data facilities, aircraft instrumentation, and flight data processing.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Systems analysis........................	5,461	6,000	9,600	**10,100**

OBJECTIVES AND STATUS

The objectives of the systems analysis effort are to identify and quantify the impact of emerging technologies in aerodynamics, materials, structures, propulsion, and systems that can lead to new plateaus or major improvements in civil or military aircraft of the future; create new markets; reduce noise and environmental impact; and provide potential new economic benefits. Conceptual designs are performed incorporating new technologies, and sensitivity analysis and trade-off studies are conducted to quantify the benefits of the emerging technologies.

In FY 1989, systems analysis for rotorcraft is concentrating on advanced configurations and propulsion systems for high-speed tiltrotors and rotorcraft. High-speed rotorcraft have the potential future application in the civil market to efficiently transport passengers between the city centers and remote airports and, in the military market, to transport both troops and equipment to remote battle locations and to perform air combat missions. Computer conceptual design codes are being improved so that the benefits of new technologies to alternative high-speed rotorcraft configurations can be quantified.

The high-speed civil transportation studies with the two major airframe manufacturers will be completed in FY 1990. This effort is identifying the most promising vehicle and propulsion system concepts for future high-speed civil transportation. The preliminary results seem to indicate that commercial supersonic passenger transportation could be environmentally compatible and economically viable with aggressive development of advanced technologies. In-house studies are also being performed in the following areas: sonic boom, community noise, environmental impact, airframe/propulsion integration, and fuels. In FY 1989, the concept feasibility is being investigated and potential benefits assessed for a supersonic throughflow engine capable of powering a supersonic transport. The concept has the potential of a 12 percent efficiency improvement over a conventional turbofan engine for this application.

Systems analysis for high-performance aircraft in FY 1989 focuses on advanced short takeoff and vertical landing (ASTOVL) aircraft. As part of a cooperative U.S./United Kingdom program, five configurations developed by contractual studies have been evaluated, and the down-selection is in process. The focus for the technology development will be on configuration-specific technologies.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The systems analysis program has been increased by $3.6 million to support h gh-speed civil transport studies and hypersonics research activities.

BASIS OF FY 1990 ESTIMATE

In FY 1990, studies will be performed on a wide variety of innovative propulsion systems that offer potential revolutionary improvements in aircraft capabilities. These analytical investigations will explore many alternative concepts and advanced technologies to identify the most promising areas of future propulsion research. Preliminary design studies will be completed on very high-pressure-ratio, ultra-high bypass ratio turbofan engines which could lead to a new generation of fuel-efficient, long-range subsonic transport powerplants. Exploratory evaluations of convertible engine concepts that could enable unconventional high-speed rotorcraft concepts will also be conducted. Analyses of candidate supersonic cruise propulsion systems will continue with emphasis on propulsion system integration with the aircraft and definition of a supersonic throughflow engine configuration. In-depth analyses of several of the most promising futuristic concepts, including beam power and superconductivity, will be conducted. Development of a NASA-wide integrated engine/airframe analysis system will be pursued with the emphasis shifting toward the incorporation of multivariate optimization, expert systems, and parallel processing features.

Systems studies for rotorcraft will continue to focus on the high-speed regime. Four contracted studies with the rotorcraft industry will be continued. These studies will provide an information base for long-range planning and a focus for research and technology programs performed by NASA and the U.S. rotorcraft industry. These system studies will assess the impact of new technologies on promising high-speed rotorcraft configurations and define future technology development requirements. Efficient high-speed rotorcraft could enhance our civil transportation system effectiveness by helping alleviate problems of air and ground congestion and enable new combat strategies and military missions. Computer codes used in the conceptual design process will be updated to enable analysis of the performance, weight, cost, and other characteristics.

The in-house systems analysis efforts will concentrate on assessing the barrier issues to high-speed commercial flight including airport noise, sonic boom, and the impact of high-speed civil transport emissions on the Earth's atmosphere. Atmospheric models will be utilized to determine the impact of aircraft emissions on the Earth's atmospheric ozone layer. Also, studies will address engine cycle and exhaust nozzle noise suppression concepts for reducing community noise. Wind tunnel testing of low boom configurations will be conducted to assess the potential of innovative aircraft configurations to reduce sonic boom over pressure levels. In conjunction with these activities, research is being conducted to determine the human response to sonic boom over-pressures and signature characteristics to identify the levels necessary for acceptable supersonic overland flight.

In FY 1990, high-performance aircraft systems analysis will focus on developing the knowledge base to effectively utilize emerging technologies to enhance fighter aircraft capabilities and to develop advanced configurations that maximize payoffs of advanced technologies. Emphasis will continue to be on supersonic short takeoff and vertical landing fighter aircraft. Studies will continue to assess the benefits of thrust vectoring control to aircraft maneuverability.

BASIS OF FY 1990 FUNDING REOUIREMENTS

SYSTEMS TECHNOLOGY PROGRAM

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Materials and structures systems technology	8,818	29,200	19,200	30,300	RD 12-28
Rotorcraft systems technology	4,529	4,800	4,800	4,900	RD 12-30
High-performance aircraft systems technology	5,430	11,000	11,000	34,900	RD 12-31
Advanced propulsion systems technology	17,955	14,000	13,952	14,500	RD 12-33
Numerical aerodynamic simulation	39.018	41.000	39,685	42.500	RD 12-35
Total	75.750	100.000	88.637	127.100	

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Materials and structures systems technology............................	8,818	29,200	19,200	30,300

OBJECTIVES AND STATUS

The objective of the materials and structures systems technology program is to develop advanced materials and structural concepts for future advanced aircraft propulsion systems and primary structures.

The objective of the advanced high-temperature engine materials technology program is to develop the technology for revolutionary advances in materials to enable the development of 21st century transport aircraft propulsion systems having greatly decreased specific fuel consumption, reduced direct operating costs, improved reliability, and extended life. This will require very high thrust-to-weight (20 to 1) gas turbine engines with durable, long-life, hot-section components which can endure sustained operation without cooling air. Key to these applications are materials capable of operating at much higher temperature and strength levels than now possible. Materials currently in use, such as titanium alloys and nickel-based superalloys, offer only minor potential gains in performance. The candidate advanced materials include ceramic matrix composites, metal matrix composites, intermetallic matrix composites, and polymer matrix composites. These materials are vital to attaining higher turbine inlet temperatures for sustained supersonic cruise, higher thrust-to-weight engines for advanced high-performance concepts, and engine hot-section components without cooling air for greater efficiency. In addition, analytical codes to design, predict life, and establish failure mechanisms will be developed to enable effective utilization of these new classes of materials by engine manufacturers.

The objective of the advanced composite materials systems technology program is to develop advanced materials and innovative structural concepts to fully exploit the benefits of composite materials for cost-effective primary structures for future aircraft applications. The program objectives will be accomplished through materials development, design and fabrication of innovative structural concepts, structural analysis and improved life prediction methods, and demonstration of improved structural performance through subscale and full-scale tests of critical components representative of advanced composite airframe structures. Composite replacements for conventional metallic structures have demonstrated that organic matrix composites can reduce airframe structural weight for primary structures on fighter aircraft and helicopters, as well as medium primary and secondary structures on transport aircraft. Thus, this program will focus on developing advanced toughened thermoset and thermoplastic composite materials; new structural concepts using cost-effective fabrication techniques such as advanced thermoforming, multidirectional weaving, pultrusion, filament winding and advanced fiber placement techniques, analysis, design and test methodologies to validate structural concepts; and analysis of failure mechanisms and methods for extending subscale laboratory tests to prediction of full-scale composite structural performance.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The materials and structures systems technology program was reduced by $10.0 million in the advanced composite materials area as a result of Congressional action on the FY 1989 budget request.

BASIS OF FY 1990 ESTIMATE

For FY 1990, advanced high-temperature engine materials research will emphasize fiber development, composite mechanics, and interfaces. Strong, stiff, lightweight reinforcement fibers which are capable of maintaining chemical stability and mechanical properties at elevated temperatures are a central issue to this entire program. Research will be pursued to develop silicon-carbide, alumina, and beryllide fibers to reinforce both ceramic and metal matrices. Studies to synthesize matrix resins for polymer matrix composites will be carried out. The mechanical behavior and failure mechanisms of composite materials under the combined influences of stress (both static and cyclic) and elevated-temperature environment are highly complex and incompletely understood. Work will be pursued at both the micro- and macro-mechanical levels. Time-dependent, visco-elastic effects, such as creep and creep-fatigue interactions, will be included. New concepts in damage mechanics will be pursued, including both analytical and experimental approaches. Fundamental understanding of elevated-temperature interface behavior under severe oxidizing conditions in metal, intermetallic, and ceramic matrix composites will be pursued. Mechanical testing and environmental durability testing capabilities will be developed for temperatures to 3000 degrees Fahrenheit and above.

During FY 1990, advanced composite materials and structures research will focus on developing fundamental technology for application of composites to primary airframe structures. This research will be directed toward exploiting new organic composite materials for use up to 600 degrees Fahrenheit and toward advanced processing and fabrication concepts for low-cost composite structures. Advanced analysis methods, including probabilistic modeling of composites for improved life prediction and analysis of composite failure mechanisms, will provide essential components of the technology required for the full use of composite materials in advanced aircraft. Advanced structural concepts will be developed and demonstrated in the laboratory for wing and fuselage primary structures using new composite materials and will include in-house structural test validation to provide the confidence essential for use of composite materials in future aircraft systems.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Rotorcraft systems technology...	4,529	4,800	4,800	4,900

OBJECTIVES AND STATUS

The rotorcraft systems technology program is significantly increasing high-speed rotorcraft research, particularly for promising opportunities for tiltrotor aircraft.

In 1989, the program is focused on noise and tiltrotor flight research. The NASA-developed comprehensive noise prediction code called ROTONET will be validated with industry to meet the prediction accuracy goal of 1.5 decibels. To meet a goal of 80 percent noise reduction, a radical planform concept is being tested in small scale. and a low-noise airfoil will be tested in full scale.

In preparation for increased high-speed rotorcraft research, tiltrotor noise is being measured and the results analyzed to determine abatement profiles for civil operation and to address detection for military use. In addition, advanced composite blades for the XV-15 tiltrotor research aircraft are in flight testing to evaluate their promise for increased maneuverability, performance, and reduced noise. Pressure-instrumented versions of these blades are being designed for future tests to understand basic aeromechanics phenomena.

BASIS OF FY 1990 ESTIMATE

In noise technology, far-field propagation and detection prediction are two acoustics issues to be investigated for military use. Validation of ROTONET for new concepts will continue. In the high-speed rotorcraft area, the pressure-instrumented tiltrotor blade will be fabricated for wind tunnel and flight testing use. Increased emphasis on technologies necessary for high-speed rotorcraft will inc ude wind tunnel investigation of the potential for active control and application of advanced computat onal techniques to the alleviation of tiltrotor download. Cooperative research will continue with the Navy for V-22 tiltrotor technology assistance.

HIGH-PERFORMANCE AIRCRAFT SYSTEMS TECHNOLOGY

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
High-performance flight research.........	5,430	11,000	11,000	9,900
High-speed research.....................	--	--	--	25.000
Total................................	5.430	11.000	11.000	34.900

OBJECTIVES AND STATUS

The objective of the high-performance aircraft systems technology program is to generate validated engineering methods and design data applicable to the development of advanced high-performance, high-speed aircraft applications. The program objectives are accomplished by analysis, ground-based simulations, wind tunnel experimental research, and flight research involving tests of advanced aircraft concepts and systems.

The F-18 high angle-of-attack research vehicle has been extensively instrumented with the goal of obtaining a flight-validated data base for the design of highly agile aircraft. Initial flight tests have provided high angle-of-attack aerodynamic data for correlation with wind tunnel and computational fluid dynamics calculations. In the NASA/Air Force F-111 mission adaptive wing (MAW) program, aircraft performance flights with both the manual and automatic control modes of the wing system have been completed. Results have been presented to the industry and user communities. The F-15 highly integrated digital electronics control (HIDEC) project, which builds on the capability developed during the digital electronic engine control (DEEC), F-100 engine model derivative, and adaptive engine control systems (ADECS) programs, has completed an assessment of advanced trajectory guidance and control algorithms and an evaluation of the maintenance diagnostic software to be used in the self-repairing flight control system tests. The F-106 vortex flap flight experiment has been completed, and the assessment of the predicted improvements in takeoff, landing, and maneuvering performance has been completed. The flight research program utilizing the first X-29 aircraft has been completed, and criteria for wing divergence and flight control systems for highly unstable aircraft have been validated and the performance benefits of the forward-swept wing were established. The second X-29 aircraft has been delivered to NASA and flight tests have begun to assess the high angle-of-attack characteristics of the unique forward-swept wing configuration. Two F-16XL aircraft were obtained from the Air Force, and exploratory research has been initiated to assess the feasibility of achieving significant laminar flow on highly swept wings of civil and military aircraft at supersonic speeds.

BASIS OF FY 1990 ESTIMATE

The flight research activity in FY 1990 will involve several high-performance aircraft tests designed to investigate advanced concepts. The F-18, modified with thrust turning vanes to enhance agility at high angle-of-attack, will be flown to evaluate the vanes' effectiveness. The assessment and characterization of X-29 forward-swept wing performance, flying qualities, and maneuverability at high angles of attack will be completed in FY 1990. Flight evaluation of a performance-seeking control system, including hardware and software, that will enhance performance improvements already demonstrated by the F-15 HIDEC, will be initiated. Flight tests of a self-repairing flight control system design, developed jointly with the Air Force to improve system failure detection and reliability, will be completed on the F-15 aircraft during this period. Computational design tools will be utilized to design supersonic laminar flow experiments which will be tested and evaluated on the F-16XL aircraft. The flight data will be used to improve and validate these tools. Flight research utilizing a YAV-8B Harrier, modified with a full authority digital electronic control system, will be initiated to investigate a broad range of flight propulsion control integration issues for short takeoff and vertical landing (STOVL) aircraft.

The high-speed research effort in 1990 covers focused efforts addressing the critical barrier environmental issues inhibiting the potential future development of an environmentally compatible high-speed civil transport. These environmental issues include the ability to satisfy atmospheric ozone depletion concerns, meet future airport noise requirements, and reduce sonic boom levels sufficiently for acceptable overland flight. The atmospheric ozone research addressed in this program involves two elements: long-term atmospheric chemistry assessment and low-emission combustor research. The long-term atmospheric chemistry assessment will use sophisticated three-dimensional atmospheric particle transport models to calculate the projected exhaust product distribution over time. These models will be used to analyze alternative fleets of high-speed aircraft with alternative operational flight profiles and levels of aircraft and engine technology. The projected exhaust product distribution will be used as input to complex two-dimensional atmospheric chemistry models to analyze the long-term effects on stratospheric ozone. In parallel with this effort, the low-emission combustor research will develop and test alternative methods for reducing or eliminating engine exhaust products that cause ozone depletion. The primary focus is to develop advanced technology combustor designs for low nitric-oxide emissions. The airport noise reduction research addressed in this program involves research on alternative engine cycles and jet noise suppression aimed at providing the technology for meeting Federal Air Regulation (FAR) 36 Stage 3 noise levels, the same levels achieved by the quietest subsonic aircraft. This research will include airport noise calculations to examine projected levels for alternative aircraft and engine systems and anechoic chamber tests of advanced technology jet noise suppressor designs. The sonic boom reduction research addressed in this program includes aircraft configuration research aimed at reducing the sonic boom levels combined with human response evaluations to define the criteria for acceptability The aircraft configuration research includes design analyses and wind tunnel testing of low sonic boom configurations, analysis and flight research on supersonic laminar flow control, and selected flight research efforts to verify the analyses and wind tunnel test results and evaluate atmospheric propagation effects and operational procedures.

ADVANCED PROPULSION SYSTEMS TECHNOLOGY

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Advanced turboprop systems...............	15,455	11,300	11,252	11,700
General aviation/commuter engine technology............................	2,500	2,700	2,700	2,800
Total....................	17,955	14,000	13,952	14,500

OBJECTIVES AND STATUS

The objective of the advanced propulsion systems technology program is to explore and exploit advanced technology concepts for future aircraft propulsion systems in high-payoff areas through the focusing of fundamental research and technology efforts and integration of advanced propulsion components.

Activities in the advanced turboprop systems program are devoted to establishing concept feasibility and providing the broad research and technology analytical and experimental data base necessary for achieving the concept's full potential. The Lewis Research Center and the NASA/industry advanced turboprop team received the prestigious 1987 Collier Trophy €or "developing advanced turboprop propulsion technology for new fuel-efficient subsonic aircraft propulsion systems." Flight tests of the nine-foot-diameter large-scale advanced propeller on the propfan test assessment (PTA) aircraft have been completed. The verified large scale propeller structural, aeroelastic, and acoustic performance and provided the first controlled data set for aircraft enroute noise. In addition, an advanced cabin treatment evaluation, near the end of the flight test, proved the potential of using tuned resonators as a lightweight treatment approach for low-noise cabins in turboprop-powered aircraft. In 1989, the aircraft will be used to obtain steady and unsteady propeller blade surface pressure measurements for code validation, as well as to extend the enroute noise data base in cooperation with the Federal Aviation Administration. Research will also continue on cabin environment in the areas of airborne and structureborne noise contributions to the cabin and lightweight cabin treatments. Analytical and experimental installation aerodynamics research will be continued with the completion of a Euler installation aerodynamics code and the associated experimental verification data base.

In the general aviation/commuter engine systems technology program, the objectives are to raise the performance level of small turbine engines to approximately that of large transport turbine engines with a decrease in fuel consumption of 30 percent. The work is focused on providing a detailed understanding of the design parameters that affect component performance through the development of analytical codes and the associated experimental data base for verification, An experimental evaluation of a compact radial inflow turbine has shown the potential for reduced turbine length with improved efficiency. Preparations are underway for experimental evaluation of cooled radial inflow turbines and uncooled composite combustor liner materials.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The advanced turboprop systems program was reduced by $48 thousand which was transferred to the Research and Technology Base to cover program support requirements in information sciences research.

BASIS OF FY 1990 ESTIMATE

In FY 1990, the emphasis in advanced turboprop systems research will be propeller source noise, cabin environment, turboprop/airframe installation aerodynamics, the evaluation of advanced propeller concepts, and the development of improved aerodynamic and structural analysis techniques for both single- and counter-rotation propellers. Aerodynamic and aeroacoustic analysis will be improved to better predict the results obtained during the propfan flight tests and to predict the effect of a leading-edge/tip-vortex flowfield recently discovered at off-design conditions such as takeoff. Airborne noise transmission codes will be validated for wing- and aft-mount Configurations using a combination of laboratory and industry flight experimental results. Increased emphasis will be placed on active noise control research as an alternate approach for lightweight cabin treatment. Turboprop/airframe installation aerodynamics code validation will be accelerated to obtain detailed wind tunnel experimental flow data for both complete aircraft configurations and with isolated nacelle/wing combinations. Advanced propeller concepts to be investigated both analytically and experimentally include increased sweep (made possible by improved analytical codes and materials), forward sweep for counter-rotation, and configurations for increased cruise speed to Mach 0.9.

The general aviation/commuter engine technology effort will continue to demonstrate component improvements through the practical application of validated analysis codes that will enable high-performance small engine systems. Application of ceramics to combustor and turbine components, cooling techniques for small radial rotors, and complete field surveys of a 4:1 pressure ratio centrifugal compressor for code validation will be emphasized in 1990.

NUMERICAL AERODYNAMIC SIMULATION

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Numerical aerodynamic simulation.........	26,018	27,500	25,927	28,500
NAS operations.........................	13,000	13.500	13.758	14.000
Total................................	39,018	41.000	39.685	42.500

OBJECTIVES AND STATUS

The numerical aerodynamic simulation (NAS) program objective is to significantly augment the nation's capabilities in computational fluid dynamics (CFD) and other areas of computational physics by developing a preeminent capability for numerical simulation of aerodynamic flows. Ongoing research and technology base efforts in computational aerodynamics will benefit significantly from the advanced computational capabilities to be provided by the NAS program. This program will provide the computational capabilities required to obtain solutions to problems which are currently intractable. The combination of these programs will provide pathfinding aeronautical research for the future, allowing solutions of the full Navier-Stokes equations and enabling the prediction of performance of complex aircraft geometries. To meet this goal, the NAS program is pursuing the following objectives: (1) acquire pathfinding, state-of-the-art, high-speed processors; (2) provide a uniform, user-friendly system with equivalent capabilities for local and remote users; (3) provide an auxiliary processing center for secure processing; (4) investigate and incorporate parallel architecture machines into future generations of the NAS; (5) provide a hardware and software development environment for prototyping and testing of computers, networks, storage devices, workstations, and graphic output devices; and (6) continue research and development of an increasingly sophisticated system of hardware/software tools and environment to assist the user in performing CFD tasks and to improve productivity.

Since NAS is both a development and operational system, two high-speed processors are necessary. The first high-speed processor (HSP-1), a Cray 2 supercomputer, has been integrated into the system in the NAS facility. The second high-speed processor (HSP-2), a Cray YMP supercomputer, was acquired and delivered in the last quarter of FY 1988. The first processor will be devoted exclusively to production computing. The second, newer and more powerful processor, will be integrated into the system while software for production use is being developed. The original NAS Cray 2 supercomputer has been dedicated for use in the auxiliary processing center for classified processing. When a new supercomputer is available with over four times the performance of HSP-2, that machine will be acquired as HSP-3. When HSP-3 is fully integrated into the NAS system, HSP-1 will be removed to make room for more advanced processors.

The **NAS** system provides a **UNIX** operating system on all levels of the system from the supercomputer to the work station. With high-speed communication links, remote users are provided an environment which is equal to local, on-site users. The **NAS** system is currently supporting over 1000 users on 335 projects at over 100 sites.

An applied research and advanced development program has been initiated to support the pathfinding goal for **NAS**. **As** part of this program, an advanced development laboratory, an advanced architecture study, and a CFD workbench project have been formed. This program will provide the capability to evaluate commercial products, to provide industry with requirements for future products, and to design new systems and software to support new architecture machines.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The numerical aerodynamic simulation program **(NAS)** was reduced by a total of **$1.3** million which was realigned to the research and technology base to cover Ames Research Center program support requirements in applied aerodynamics and information sciences research and technology. Within this program $0.3 million was also realigned from **NAS** development to **NAS** operations to provide needed funding in that area.

BASIS OF FY 1990 ESTIMATE

FY 1990 will be an important year in the development of the **NAS** system. The acquisition of the third high-speed processor will be initiated. With the second processor integrated into the system, the number of users and projects supported by **NAS** will increase accordingly. Support processing will be upgraded to satisfy the additional requirements of the system. To meet the challenge of providing one tera floating point operations (TFLOP) computing capability by the year 2000, a highly parallel testbed facility will be established for the development and demonstration of highly parallel computer technologies, including architectures, algorithms, and system software.

TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — **TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Transatmospheric research and technology..........................	52.500	84.400	69.400	127.000	RD 13-2
Total...............................	52.500	84.400	69.400	127.000	

Distribution of Program Amount by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Ames Research Center....................	4,324	4,000	4,550	5,000
Langley Research Center..................	9,888	13,200	8,800	9,000
Lewis Research Center..................	8,081	3,600	6,060	6,000
Headquarters...........................	30.207	63.600	49.990	107.000
Total	52.500	84.400	69.400	127.000

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY **TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY**

PROGRAM OBJECTIVES AND JUSTIFICATION

The transatmospheric research and technology program is a portion of the joint NASA/Department of Defense (DOD) National Aero-Space Plane (NASP) program. FY 1990 is the last year in the NASP Phase 2 program plan and will establish the technology base for the decision in the last quarter of calendar year 1990 as to whether to proceed to Phase 3 which is the design, construction, and flight testing of the X-30. Activities in this last year of Phase 2 (FY 1990) are directed toward completion of all contracted and technology maturation tasks now underway and toward providing the plan for the X-30 procurement and testing. There will be special emphasis on testing of components and hardware acquired earlier in the program, with extensive test programs to be accomplished in a variety of NASA and many other government- and contractor-owned facilities. There will be a concentrated effort to complete the computational fluid dynamics (CFD) design methods and analysis programs that have been developed and evaluated in the conduct of the Phase 2 program. Each of the contractors and the government design team will provide a risk assessment and complete an independent assessment of the technologies and their integration into vehicle concepts that will satisfy the NASP program goal of a reusable, hydrogen-fueled, airbreathing, horizontal takeoff and landing, aerospace plane with single-stage-to-orbit capability.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The transatmospheric research and technology program has been reduced by $15.0 million as a result of Congressional action on the FY 1989 budget.

BASIS OF FY 1990 ESTIMATE

In the contracted portion of the NASP program, three airframe contractors (General Dynamics, McDonnell-Douglas, and Rockwell International) will each complete contractually-mandated design, fabrication, and thermal and loads testing of a cooled wing leading edge section, a large wing-fuselage juncture structural section, and an insulated, 1000-pound liquid hydrogen tank-fuselage test section. The design, analysis, and test results of these component activities, and data available from the technology maturation program, along with the vehicle concept definition activities integrating each engine concept will provide the basis for each airframe contractor's X-30 vehicle proposal submission in October 1990. Both engine contractors (Pratt 6 Whitney and Rocketdyne) will complete all component testing, accomplish construction of the contractually-required large-scale, proof-of-concept module of their engine cycle, and will conduct an extensive test program through Mach 8 simulation of pressure and temperature in one of the two vitiated, continuous flow, government-furnished engine test facilities (ETF) on the west coast at the Marquardt Corporation and Aerojet General Corporation. The results of these large-scale, steady-state test activities, taken together with all other data available from the technology maturation program, will provide the basis for the X-30 engine proposals in October 1990.

The technology maturation portion of the NASP program, which is a large array of high-risk, enabling technology tasks in selected discipline areas, will be completed and the data and results distributed and disseminated to the U.S. aerospace industry. The Innovative Industry Materials Consortium in advanced high-temperature materials technology is a major ($145 million) activity within the technology maturation program. The results will include characterization of advanced carbon-carbon with coatings and reduced weight; titanium-aluminide alloy characterization and various fiber reinforcement systems; several new alloy processes for high-temperature, creep-resistant applications, particularly for regeneratively cooled engine structural applications; and a major effort directed at materials formulations with reduced sensitivity to hydrogen embrittlement.

Completion of the technology maturation CFD activities will yield the largest concentrated effort in high Mach number flow analysis and wind tunnel verification since design of the shuttle in the early 1970's. CFD methods will provide extensive three-dimensional analysis capabilities for both internal and external flows and, for the first time, "real gas" effects at flow conditions above Mach 12.

Efforts in scramjet combustor flow analysis and fundamentals, along with precision high-rate instrumentation and measurements, provide computational and experimental work in the physical and chemical processes that occur in and control the performance of this engine'concept. Work in lower speed (Mach 0 to 6) propulsion systems addresses component performance and component/vehicle integration. Variable geometry inlet concepts and forebody flowfield effects on engine performance have been analyzed, and experimental testing will be completed on several different configurations in FY 1990. Unconventional nozzle configurations and afterbody shapes/contours have been analyzed, and testing will be completed. Performance/penalty tradeoffs over the operating Mach number range of the vehicle will be reported.

Hypersonic aerodynamics experiments over the full operating range (Mach numbers 0 to 25) for a variety of vehicle configurations will be completed and reported. In addition, a major effort in the theory, analysis and experimental measurement of laminar to turbulent boundary layer transition will be completed. This work, providing design criteria for both generic vehicle drag prediction and heat transfer at hypersonic speeds, is being accomplished at NASA Langley utilizing the available low disturbance wind tunnel facilities. These data are required by the NASP contractors for the accurate and consistent prediction of the engine and airframe performance in the X-30 design proposals.

Slush hydrogen is a mixture of solid and liquid hydrogen. Its characterization and thermal management tasks are also being addressed in the technology maturation program. The potential of increased thermal capacity and increased density represents major technological improvements for hypersonic vehicle systems. Flow analysis, production, and storage methods for both ground and airborne systems are being studied and tested in government and contractor facilities. These data will be incorporated into the X-30 vehicle design and performance assessments during proposal development.

SPACE RESEARCH
AND TECHNOLOGY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — **SPACE RESEARCH AND TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
	(Thousands of Dollars)				
Research and technology base	107,146	134,100	134,100	130,100	RD 14-4
Civil space technology initiative (CSTI) program	114,154	156,800	121,800	144,500	RD 14-26
Pathfinder program	--	100,000	40,000	47,300	RD 14-30
In-space experiments technology program	--	--	--	16,200	RD 14-33
Total	221,300	390,900	295,900	338,100	

Distribution of Program Amount by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center	9,695	24,000	14,000	16,400
Kennedy Space Center	402	4,300	1,000	700
Marshall Space Flight Center	36,062	71,400	44,100	66,000
Goddard Space Flight Center	7,571	11,600	7,500	9,800
Jet Propulsion Laboratory	31,524	48,000	40,300	49,400
Ames Research Center	24,354	37,100	32,800	33,400
Langley Research Center	52,435	65,600	58,500	58,700
Lewis Research Center	39,181	74,500	60,400	66,600
Headquarters	20,076	54,400	37,300	37,100
Total	221,300	390,900	295,900	338,100

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — SPACE RESEARCH AND TECHNOLOGY

PROGRAM OBJECTIVES AND JUSTIFICATION

The overall goal of the space research and technology program is to provide advanced, enabling technologies, validated at a level suitable for user-readiness, for future space missions in order to ensure continued U.S. leadership in space to meet national needs. To achieve this goal, a commitment is required to provide a broad base of advanced technology for vehicle and subsystems concepts, components, devices, and software; to develop technology strengths in the engineering disciplines within NASA, industry, and academia; and to perform critical technology demonstrations that facilitate the transfer of new technology with a high level of confidence to future space missions.

The space research and technology program consists of two basic program areas, the research and technology base and focused programs. The objective of the research and technology base program is to gain a fuller knowledge and understanding of the fundamental aspects of phenomena and observables in critical disciplines. Within the research and technology base program, high-leverage technological advances and concepts are brought to the level of demonstrating proof of principle. The base program is the seedbed for generating the more highly mission-focused technology programs.

Focused programs, designed and implemented based on requirements provided by the potential users of the technology, develop technology for specific applications and deliver products in the form of proven hardware, software, and design techniques and data. Two focused programs are currently underway, the Civil Space Technology Initiative (CSTI) and Pathfinder. The CSTI program is a positive first step to strengthen the agency's technical base and provide options for future low Earth orbit high-priority civil space goals. CSTI is developing technologies to enable efficient, reliable access to Earth orbit; enhance operations in low Earth orbit; and increase the effectiveness of science missions from low Earth orbit. The Pathfinder program, an element of the new national space policy, is developing critical capabilities to enable potential future missions, both human and robotic, to expand human presence and activities beyond Earth's orbit into the solar system. It will push U.S. technology forward through a strong partnership between NASA, industry and universities. Proof-of-concept testing for mission-critical engineering designs will be an important product of the CSTI and Pathfinder programs and will directly support the continuing evolution and maturation of mission plans.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The space research and technology program was reduced by $95.0 million ($35.0 million in CSTI and $60.0 million in the Pathfinder program) as a result of Congressional action on the FY 1989 budget request.

BASIS OF FY 1990 ESTIMATE

In FY 1990, the research and technology base program will continue to explore newly emerging areas that offer longer range, high-leverage program benefits. The base program consists of ten discipline elements: aerothermodynamics, space energy conversion, propulsion, materials and structures, space data and communications, information sciences, controls and guidance, human factors, space flight, and systems analysis. In addition, the university space research program, supported by the research and technology base, will continue to enhance and broaden the capabilities of the nation's engineering community to participate more effectively in the U.S. civil space program. The space research and technology program will continue to support the planned research and development activities of the two ongoing focused programs, CSTI and Pathfinder, and will be augmented to initiate the In-space Technology Experiments (INSTEP) program.

The objectives of the CSTI program are focused on research in three broad categories -- transportation, operations, and science technology. The research is targeted at opportunities with clearly defined end objectives to validate technology advances. Specific program elements are: automation and robotics, propulsion, power, information technology, large structures and control, and vehicle technology.

The Pathfinder program, begun in FY 1989, will develop a broad set of technologies to enable potential future robotic or manned solar system exploration missions. The Pathfinder program is divided into five major thrusts: surface exploration, in-space operations, humans in space, space transfer vehicles, and mission studies.

The In-Space Experiments Technology program is an important new program designed to provide validated, advanced space technologies to the designers for improving the effectiveness and efficiency of current space systems and to provide major advancements for future systems. Previous efforts over the past few years have identified advanced, highly innovative technology concepts that require testing or validation in the actual space environment in order to reduce the risk to the potential users, to increase the rate of transfer of advanced technologies into future space missions, and to begin to prepare for conducting technology experiments using Space Station Freedom.

BASIS OF FY 1990 FUNDING REOUIREMENT

RESEARCH AND TECHNOLOGY BASE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Aerothermodynamics research and technology............................	10,170	11,500	10,900	10,500	RD 14-5
Space energy conversion research and technology............................	12,154	13,800	13,800	12,900	RD 14-7
Propulsion research and technology.......	12,679	19,700	16,600	15,200	RD 14-9
Materials and structures research and technology............................	17,215	17,500	20,000	21,600	RD 14-11
Space data and communications research and technology........................	7,765	9,300	9,300	8,800	RD 14-13
Information sciences research and technology............................	7,428	9,000	7,700	7,500	RD 14-15
Controls and guidance research and technology............................	5,260	6,700	6,700	5,600	RD 14-18
Human factors research and technology............................	4,047	5,300	5,300	4,600	RD 14-19
Space flight research and technology............................	21,052	18,100	20,600	19,400	RD 14-20
Systems analysis........................	5,376	6,900	6,900	6,900	RD 14-22
University space research................	4.000	16.300	16.300	17.100	RD 14-24
Total.................................	107.146	134,100	134,100	130,100	

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Aerothermodynamics research and technology............................	10,170	11,500	10,900	10,500

OBJECTIVES AND STATUS

Future aerospace vehicles, such as aeroassist space transfer vehicles (ASTV), aerospace planes, and hypersonic cruise and maneuver vehicles, must be capable of sustained hypervelocity flight in both rarefied and continuum flow regimes. The design of these vehicles presents formidable challenges to current prediction methodologies. To meet these challenges, the aerothermodynamics program is pursuing the following objectives: (1) development and application of advanced computational methods and numerical techniques covering the entire spectrum of continuum, transitional, and rarefied flows; (2) development of accurate and detailed real-gas chemistry and high-speed turbulent flow models and the efficient integration of these models with standard computational flow codes; (3) establishment of a high-quality ground and flight experimental data base for code validation and verification; (4) direct correlation and comparison of computations with available ground and flight data; (5) establishment of a detailed aerothermal loads data base and development of fully integrated analysis techniques; and (6) enhancement of engineering design codes and advanced configuration analysis capability to support rapid evaluation of future vehicle/mission concepts.

Progress continues to be made in the development of computational fluid dynamics (CFD) codes for simulating hypervelocity rarefied flowfields. In addition to the ongoing work with the direct simulation Monte Carlo techniques, a newly developed, highly efficient particle kinetic simulation scheme--which is based on new algorithm concepts using massive high-speed computer memory and higher order molecular collision models--is being developed to simulate high-altitude, low-density nonequilibrium hypersonic flows of diatomic gases. These schemes will be pushed through the transition regime toward the continuum regime.

In addition to the development of these particle kinetic simulation schemes, new efficient schemes for low-density hypersonic flows in thermochemical nonequilibrium are being developed. These schemes use newly developed constitutive relations and slip conditions that will permit extension of continuum-based methodologies for real-gas Navier-Stokes simulation into the rarefied regime.

Numerical flowfield simulations for the aeroassist flight experiment (AFE) continue to provide data bases to support the structural loads, aerodynamics, aerothermodynamics, and science requirements for design and operational purposes. Full-body AFE flowfields have been developed at both wind tunnel and AFE flight conditions to help highlight real-gas effects on the flowfield and design parameters.

Complementary to the development of computational fluid dynamics (CFD) codes and numerical simulation capability is the requirement to establish a high-quality aerothermodynamics experimental data base applicable to a wide range of vehicles and flow conditions. In addition to the aerodynamics and aerothermodynamics data bases being developed in conventional wind tunnels, data are being obtained from ballistic ranges, shock tubes, and high-velocity flight programs for use in validating CFD codes with real-gas features.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The aerothermodynamics research and technology program has been reduced by $0.6 million. This reflects a realignment of hypersonic research to the materials and structures research and technology program.

BASIS OF FY 1990 ESTIMATE

The FY 1990 program in computational methods will continue to emphasize techniques for efficient coupling of real-gas chemistry models to Navier-Stokes flowfield codes. This will involve the development of more sophisticated chemistry models--based on computational chemistry results--and more robust and computationally efficient solution algorithms. Work will also continue on the development of user-friendly adaptive grid generation techniques, which can be applied to a variety of flowfields and configurations. These improved capabilities will permit more accurate simulation of continuum flow around advanced space transportation vehicles under both ascent and entry conditions.

In the area of direct simulation techniques, the focus will continue on developing the highly efficient particle kinetic simulation method. Results from this method will be compared with benchmark results from the more computationally intensive Monte Carlo method to determine the range of application for the more efficient particle kinetic simulation method. The particle kinetic simulation holds great promise for enabling rapid parametric studies of maneuvering vehicles in the upper atmosphere.

Expansion of the current aerothermodynamic experimental data base will continue, with emphasis being given to experiments aimed at code calibration and validation. Specifically, experiments will be aimed at providing nonequilibrium flows around a variety of configurations. To this end, use of NASA's high-enthalpy/high-velocity ballistic ranges and shock tubes will be increased and the development of nonintrusive diagnostic measurement techniques for hypersonic flow will be actively pursued to enable realistic hypersonic experimentation in ground facilities.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Space energy conversion research and technology............................	12,154	13,800	13,800	12,900

OBJECTIVES AND STATUS

The objective of this program is to develop technology alternatives that improve performance, reliability, and cost effectiveness of space power for manned space operations, as well as autonomous Earth-orbiting and planetary exploration spacecraft. To meet the challenge, improvements of a factor of two to five and increased life potential are being sought in alternative solar power generation components, chemical energy conversion systems, energy storage systems, electrical power management and distribution, as well as the thermal management systems. For spacecraft photovoltaic technologies, the goal is to improve the total system performance enough to permit a 50 percent increase in payload mass, while not increasing the spacecraft overall mass. For environmental control and life support systems, the goal is to provide a technology base in chemical processing techniques to support future human space missions.

Recent developments in the photovoltaic (solar power) area include a 22 percent efficient gallium arsenide concentrator solar cell, testing of radiation-resistant indium phosphide solar cells, and a twofold improvement in solar panel specific power to over 130 watts per kilogram.

NASA's Lewis Research Center received a "Research & Development 100" award for demonstrating long-lived nickel-hydrogen battery performance for low Earth orbit applications. This battery, which has about ten times the cycle lifetime of existing flight systems, will be used on Space Station Freedom and on the Hubble Space Telescope. Research on advanced rechargeable batteries, such as lithium-titanium-disulfide, has demonstrated in laboratory-scale tests the potential for achieving 80 watt hours per kilogram which is about four times current capabilities.

Advanced solar dynamic concentrator technology with 25 percent of the mass per unit area of those under consideration for future use on the Space Station Freedom has been demonstrated, and receiver concepts with one-half the mass of those proposed for Space Station have been identified.

BASIS OF FY 1990 ESTIMATE

For spacecraft photovoltaic technologies, functional testing will be completed on a lightweight prototype wing involving 12 panels with the long-term goal of having a solar array with 300 watts per kilogram that can withstand launch and on-orbit environments. Such specific power is about five times better than the best that has been flown. Research will continue on developing 20 percent efficient indium-phosphide solar cells which can withstand high radiation environments such as those in the Van Allen radiation belts around Earth and in the radiation belts around Jupiter.

Critical technology experiments will be initiated on two advanced solar dynamic receiver concepts (one based on the Stirling cycle, the other based on the closed Brayton cycle), and the demonstration of lightweight, highly accurate solar concentrator technology will continue. Planned advancements in this area will result in a factor of three improvement in the specific power of solar dynamic power systems. Analyses of thermal energy storage systems will be completed and work started on thermal energy storage materials for testing on an eventual flight experiment. Materials with high thermal conductivity and high heat of fusion are needed to develop efficient and lightweight thermal energy storage systems and receivers.

Work will continue on extending the performance of lithium-titanium-disulfide batteries to reach a 1000-cycle lifetime which would make such a battery suitable for future planetary missions and on conducting advanced nickel-hydrogen battery cell tests leading toward the goal of 100 watt hours per kilogram, which is about five times greater than the current state of the art.

Experimental and analytical efforts to study droplet formation, heat transfer mechanisms and zero-gravity phase change, and fluid flow phenomena will be conducted to evaluate materials and designs and develop the required technology base for advanced radiator concepts that will allow the large amounts of heat generated by high power systems to be dissipated. High-frequency power system designs and components will be developed to reduce the weight, increase the life, and meet the space radiation and temperature constraints. Experimental power systems, biased to simulate space charging effects, will be tested in vacuum chambers to determine the possible detrimental effects of high-voltage arcing and to develop designs which will be suitable for use in civil missions.

Research will continue on developing efficient air, water, and waste processing technologies, sensor and monitoring instrumentation and controls technology for air and water quality, as well as the development and validation of computerized simulation techniques to support and guide the research effort.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Propulsion research and technology.......	12,679	19,700	16,600	15,200

OBJECTIVES AND STATUS

The objectives of the propulsion research and technology program are to develop and validate accurate analytical simulations of the chemical and physical processes that occur in space propulsion systems and to evaluate the potential benefits and feasibility of advanced concepts that will improve our propulsion capabilities well beyond those that are achievable with today's operational systems. Included are propulsion systems for advanced transportation systems and for planetary ascent vehicles. Also included is Earth-orbiting satellite auxiliary propulsion needed for such functions as attitude control and station keeping. Finally, a part of the program is dedicated to the identification and evaluation of very high-energy advanced propulsion concepts that, if proven feasible and ultimately practical, would provide a quantum leap in propulsion capabilities that could be applied to a number of the above applications.

Advanced transportation propulsion technology is directed toward the continued expansion of fundamental knowledge and understanding of rocket engine processes and principles and toward advanced concepts leading to more efficient and effective component and engine systems that will provide enhanced payload delivery capability for future space transportation vehicles. Fundamental efforts are focused on the development and experimental verification of combustion instability codes, unified computational fluid dynamics codes, impeller flow models, soft seal rub dynamic models, and fluid dynamic processes in combustion chambers and nozzle boundary layers. Considerable progress has been made in development of analytical representation of these phenomena. Experimental verification of these analytical models and techniques remains to be accomplished. Advanced concept efforts concentrate on promising design concepts and high energy density propellant combinations to provide enhanced propulsion system performance.

Emphasis is on metallized gelled propellants, compliant thrust chamber fabrication techniques, and high-temperature (4000 degrees Fahrenheit) combustor materials. Hydrocarbon fuels have been successfully gelled and metallized (with aluminum) and flow characteristics established.

Lunar/planetary propulsion technology is directed toward the exploration and evaluation of propulsion concepts utilizing planetary in-situ propellants to reduce Earth launch vehicle requirements for potential future space exploration missions. Studies indicate oxygen and aluminum could be extracted from lunar soil and that oxygen and carbon monoxide could be obtained from the carbon dioxide in the Martian atmosphere.

Primary emphasis is on lunar-derived propellants, with the most attractive concept being a gelled aluminum/oxygen monopropellant. Efforts are focused on safety and handling characteristics and on propellant rheology.

Auxiliary or low-thrust propulsion technology is directed toward improved capabilities in resistojets, arcjets, ion thrusters, magnetoplasmadynamic (MPD) thrusters, and long-life, efficient gaseous and storable liquid chemical propellant rockets. The program has already achieved a number of notable successes including: (1) achievement of an extraordinary increase in chamber wall temperature with conventional chemical propellants leading to a 20-second increase in the specific impulse for standard chemical engines; (2) completion of 1000-hour, 500-cycle autonomous life test of an arcjet with a high specific impulse of 450 seconds; and (3) completion of a 500-hour, 10-kilowatt ion engine life test.

Advanced propulsion concepts studies continue to investigate promising capabilities not yet within our reach. Efforts include determining the critical research needs for antimatter propulsion and the selection of critical experiments, evaluating the status of fusion propulsion and selecting possible applications to NASA missions, and appraising the ram cannon. A magnetically confined microwave-induced plasma experiment has been initiated at the Massachusetts Institute of Technology as the first experimental effort under the advanced concepts program.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The propulsion research and technology program reflects a reduction of $3.1 million, which consists of a $2.5 million realignment to space flight research and technology for cryogenic research efforts and a realignment of $0.6 million of hypersonic research to materials and structures research and technology.

BASIS OF FY 1990 ESTIMATE

In the advanced transportation propulsion program, efforts in 1990 will be aimed at developing an experimental data base for validating combustion instability analyses. Efforts also will be initiated to quantify the ignition and combustion characteristics of metallized hydrocarbon gel fuels, and activities will be directed toward promising cryogenic metallized propellants to study propellant rheology and ignition and combustion physics. Testing of very high-temperature materials (4000 degrees Fahrenheit) as potential combustor liners also will be conducted.

In the lunar/planetary propulsion program, efforts in 1990 will be directed toward establishing the safety and handling characteristics of oxygen/aluminum monopropellants. Laboratory experiments will be conducted to understand the physics of gelling liquid oxygen and aluminum mixtures. Combustion devices will be fabricated and tested to investigate the ignition and combustion characteristics of lunar/planetary derived propellants.

A combustion shear layer model of low-thrust chemical rocket combustion will be developed as part of the overall effort to understand the fundamental physics of rocket combustion, A 50-kilowatt arcjet facility will be completed and made operational with plans to complete the initial life tests of a 5-kilowatt arcjet in FY 1991. As part of the continuing effort to improve the performance of ion engines for future space exploration a 100-hour life test of a 50-kilowatt ion engine will be completed. This will mark a significant milestone on the way to advanced electric propulsion. Work will continue on moving to higher power levels (over 200 kilowatts) on MPD thrusters to determine the degree of efficiency enhancement.

Advanced propulsion concept studies will continue toward the objective of identifying the most fruitful areas for agency emphasis and the critical experiments necessary to prove their potential. The magnetically confined, microwave-induced plasma experiment at the Massachusetts Institute of Technology will be in full test operation.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Materials and structures research and technology...........................	17,215	17,500	20,000	21,600

OBJECTIVES AND STATUS

The objective of the materials and structures program is to provide technology that will enable the development of future spacecraft, large-area space structures, and advanced space transportation systems with significant improvements in performance, efficiency, durability, and economy. Major technical areas of emphasis focus on fundamental understanding of the processing; properties and behavior of advanced space materials, including long-duration synergistic space environmental effects on materials; development of lightweight space-durable materials; computational methods in chemistry to enable the prediction of physical properties and environmental interactions involving materials under space and reentry conditions; nondestructive measurement science for advanced materials; tribological aspects of materials behavior in the space environment; and the development of a wide variety of metallic, intermetallic, ceramic and carbon-carbon materials for thermal protection systems. Structures technology focuses on the development of erectable and deployable structural concepts; methods for in-space construction, monitoring, and repair of large complex structures; dynamics of flexible structures and concepts for active configuration control and vibration suppression; new structural concepts for active cooling of hot structures and cryogenic tanks for advanced Earth-to-orbit rocket propulsion systems, hypersonic vehicles, and orbital transfer vehicles; and efficient analysis and design methodology for advanced space structures, including multidisciplinary analysis and optimization.

In the materials science program, efforts are underway to theoretically develop and experimentally verify methodologies for predicting the properties of polymers, to develop new high-toughness high-temperature polymers, to develop new nondestructive measurement capabilities using acoustic microscopy and fiber optic systems, and to conduct fundamental studies of solid lubricants in the space environment. In the space durable materials program, contamination studies are focusing on the development and verification of analytical codes for correlating in-flight data and ground-based experiments. Atomic oxygen studies include developing new ground-based atomic oxygen simulation facilities, conducting a program to compare and calibrate a wide range of ground-based facilities for simulating atomic oxygen exposure in low Earth orbit, and measuring long-term atomic oxygen exposure effects on various organic materials. In the area of micrometeoroid/debris impact, ground-based experimental studies of hypervelocity impact on metallic and nonmetallic materials are continuing and, in the area of radiation exposure, a new facility is being developed to provide a combined thermal-cycling/electron-radiation capability. In the aerothermal materials program, processing, fabrication and testing of various ceramic materials for thermal protection systems are being carried out. In the generic hypersonic program, work is underway to develop, fabricate and evaluate very thin gage oxidation-resistant intermetallic and carbon-carbon materials for lightly loaded hot structures.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The materials and structures research and technology program was increased by $2.5 million. This includes a research and technology base realignment of $1.2 million to this program for hypersonics research and a realignment of $1.3 million for the upgrade of the central computer facility at the Ames Research Center.

BASIS OF FY 1990 ESTIMATE

In FY 1990, the materials program will continue to place a strong emphasis on space environmental effects on materials and on developing materials with enhanced space durability. The space durable materials program will focus on developing new ground-based capabilities for accelerated materials testing, on the development of analytical capabilities to predict long-term in-space materials performance from ground-based studies, and on flight experiment opportunities provided by collaborative efforts with the European Space Agency and the Department of Defense. Computational chemistry studies will focus on developing and verifying capabilities to predict the properties and behavior of bulk polymers. Nondestructive measurement studies will focus on new capabilities to quantify microstructural parameters and fatigue damage characterization in metals. An area which will begin to receive greater emphasis is tribology in the space environment in coordination with a planned new structures initiative in space mechanisms.

The aerothermal materials and structures activity will continue development and testing of lightweight cryogenic tank concepts and advanced ceramic thermal protection systems (TPS) with higher temperature capability (approximately 3000 degrees Fahrenheit) and high structural strength. Design and analysis emphasis will be placed on validating design concepts for curved tank structures. Curvature causes more severe, realistic, thermal stresses than flat panels, which may not be suitable for complex shapes. Integral and separate cryogenic tank subscale components will be fabricated and tested to validate design concepts for advanced thermal protection systems and structural integrity. Ceramic composite TPS design concepts, including advanced fabrication methods using improved multiaxis weaving, will be continued in FY 1990.

The goal of improving transverse mechanical properties by at least 50 percent will be emphasized to enable effective use of ceramic composites as both structural components and TPS. Here, as well, cured TPS ceramic-ceramic concepts will be fabricated and validated using arcjet tests required to achieve the high heating rate environments for hot structures. These activities will be supported by a strong program in analytical and experimental methods to predict aerothermal loads. An increasing part of this activity will be extensive testing of hot structures, including cryogenic tankage concepts.

The effort in space-related hypersonics will emphasize generic concepts for lightweight structures with complex shapes, including novel concepts for areas of extreme heating, such as leading edges and nose caps. One concept currently under study, in small scale, is a spinning leading edge. Advanced joining and shaping methods will be studied for thin-gauge sheet and multiwall concepts, again emphasizing curved complex surfaces. Work also will continue on carbon-carbon materials including methods to improve transverse properties. Various coating concepts will be explored to improve oxidation resistance of advanced carbon-carbon composites. Small-scale components will be fabricated and tested under simulated service environments up to 3000 degrees Fahrenheit to assess the potential for carbon-carbon high-temperature structures for hypersonic vehicles.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Space data and communications research and technology........................	7,765	9,300	9,300	8,800

OBJECTIVES AND STATUS

The space data and communications research and technology program is directed toward developing technology to control, process, store, manipulate, and communicate space-derived mission data and enabling new communications concepts.

In the area of advanced data systems, neural network devices for high reliability space applications have been demonstrated. These neural memory devices may have the potential to replicate the capability of the human mind for pattern recognition and deductive reasoning and will serve as hardware-based natural intelligence for space applications. A pilot application and evaluation of a software management environment was completed. An advanced software life-cycle simulation development was applied to a model of the space station software development environment. These tools are intended to provide software managers with critical tools for evaluation of software development cost and schedule. A reusable software component library in an Ada development laboratory was demonstrated.

Reliable, ultra-high-rate, communications links for future NASA missions are predicated upon the communications research and technology base. Prototype Ka-band monolithic microwave integrated circuits have been designed, fabricated and tested. These circuits are planned for use in phased-array antennas for future deep space missions, such as Cassini and the Mars Rover. An experiment was successfully conducted on a multiple element phased-array feed with electronic compensation for antenna distortion. A near perfect far-field antenna pattern was produced. Such a concept will find application in large radiometry antennas for Earth remote sensing at the 10 to 100 Gigahertz frequencies. Continuing tests on a gallium aluminum arsenide semiconductor laser operating at 30 degrees Centigrade and at a modulation rate of 100 Megahertz showed a minimal drop in power which is projected to provide a life of four years of continuous operation. Long lifetime space-qualifiable lasers are critical for practical space optical communications. For deep space communications applications, a semiconductor diode array was successfully employed in pumping a yttrium-lithium-fluoride solid-state laser doped with holmium and erbium to emit at the eye-safe wavelength of two micrometers. Finally, a complete monolithic solid-state photodiode with ten amplification stages was fabricated and successfully tested at 25 degrees Centigrade with a gain of 200 times in signal strength and a bandwidth of greater than two Gigahertz. This device represents a significant technical achievement for reception of space optical communications signals.

BASIS OF FY 1990 ESTIMATE

An erasable neural network-based associative memory system for high reliability space applications will be demonstrated. A generic software life-cycle model will be validated by application to a number of NASA-managed software projects. The software management environment development will be completed, and expert system approaches for dynamic simulation of various software systems will be demonstrated toward meeting the objective of providing a complete and integrated set of tools and measures for management and acquisition of major software systems. Funding will be provided to continue support for the software engineering research center at the University of Houston at Clear Lake for continued research in Ada software development, integration, and validation for embedded and distributed systems.

In FY 1990, work will continue on increasing the productivity yield of monolithic microwave integrated circuits, since many of these circuits are needed in a full-scale flight phased-array antenna microwave link. The electronic compensation of distorted antennas will be scaled to radiometric antenna sizes and frequencies needed for geostationary Earth observations. A monolithic phased-array of ten-edge emitting semiconductor laser diodes will be successfully combined into a single far-field beam. Additional work will concentrate on various methods and techniques for modulating the beam at rates in excess of 100 Megahertz. Surface-emitting semiconductor diode arrays are a new promising technology with peak powers in the range of watts. Various methods for modulating surface-emitting diode arrays at rates in excess of 100 Megahertz will be investigated. In the deep space laser communications applications area, techniques for modulating the semiconductor pumped solid-state lasers will also continue., The solid-state semiconductor avalanche photodiode devices will be investigated to ascertain the gain versus parameters such as the number, composition, and size of the superlattice layers.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Information sciences research and technology	7,428	9,000	7,700	7,500

OBJECTIVES AND STATUS

The objective of the information sciences research and technology program is to provide new concepts, techniques, system algorithms and architectures, hardware devices and components, and software in order to enable viable and productive space information systems.

In the computer sciences area, the distributed access view integrated data base (DAVID) system software has been built and tested to provide scientific users a transparent access to space data stored in dissimilar data bases. Demonstrations of DAVID for astrophysics applications have been given. The new center of excellence in space data and information sciences (CESDIS) was established at Goddard Space Flight Center in conjunction with the University of Maryland. A prototype intelligent data management front end using natural language, expert systems graphics, and a knowledge-based data management controller was integrated and demonstrated. In the concurrent processing research area, additional algorithms were successfully run on the massively parallel processor, including graphics/visualization, data base string search, and flow reactor simulation.

In the sensing area, the goal of high spatial imaging with simultaneous sharp energy resolution for x-ray and gamma-ray imaging spectrometers and cosmic-ray drift detectors has been advanced by the technique of employing a silicon drift detector to achieve better than 100-electron volt energy resolution over the soft X-ray spectrum to 10,000-electron volts in energy. These concepts have immediate application to the advanced X-ray astronomical facility and AstroMag missions. A semiconductor diode laser fabricated from gallium antimonide with indium and arsenic in various layers has successfully operated at the eye-safe region of 2.1 micrometers in wavelength at 77 degrees Kelvin. Such a demonstration means that laser systems at this wavelength have the potential of being injection locked for frequency stability.

In the photonics area, a real-time acoustic spectrum analyzer with frequency resolution of 50 Kilohertz over a bandwidth of 24 Megahertz has been demonstrated. This analyzer has immediate potential for use in the Microwave Observing project. In addition, a liquid crystal television spatial light modulator for image subtraction, edge enhancement and associative memory applications has been demonstrated for application to robotic image identification and recognition.

The area of high-temperature superconductivity has generic application across the spectrum of NASA uses Research using a scanning tunneling microscope has ascertained that the surface of yttrium-barium-copper-oxide high-temperature superconducting material is not superconducting. This result will impact the fabrication of devices utilizing the surface properties of these materials.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The information sciences research and technology program reflects a reduction of $1.3 million, which was realigned to the materials and structures research and technology program for upgrade of the central computer facility at the Ames Research Center.

BASIS OF FY 1990 ESTIMATE

In computer sciences, research will be conducted under four major themes: information management, concurrent processing, software engineering, and artificial intelligence. The block grant funded center for aeronautics and space information systems (CASIS) at Stanford University will conduct research in neural networks and cellular automation, man-machine systems, high-speed network and telecommunications and signal processing. The recently established center for excellence in space data and information sciences (CESDIS) at Goddard Space Flight Center will stimulate university and industrial research on NASA long-term space and earth sciences data and computational problems through the peer-reviewed research proposals.

Artificial intelligence techniques for information extraction and autonomous decision making, utilizing high-dimensional multispectral and multisensor image and nonimage data, will be developed and demonstrated.

A generic software engineering process simulation (SEPS) model assessing the effect of changes in technology, software engineering development environment, and management policy on various software development projects will be developed.

Fundamental research in automated technology for ingest, identification, categorization, and systems management and control of object-oriented data sets will be initiated; research in intelligent data base management processes, such as intelligent query formulation and search strategies based on expert knowledge, will continue, as well as research on concurrent processing algorithms for space research and data analysis.

Evaluation and validation of fundamental principles of concurrency for reliable and parallel computer architectures will be conducted, and applications and benefits of conceptually new memory technology in concurrent processing applications will be evaluated.

Several technologies will be developed for high-energy astrophysical research, including a detector with maximum energy range and simultaneous energy resolution. A demonstration of an X-ray cooled calorimeter spectrometer with 10-keV sensitivity for x-rays from 0.1 to 10 keV, and a room temperature X-ray and gamma-ray spectrometer employing detectors and arrays made from mercuric iodide appears promising. The 2.1-micrometer wavelength region is technologically interesting because detectors exist that can enable better measurements of coherent backscattered radiation. Since this region is also of scientific interest to earth observations, research will continue on a laser system configuration for remote sensing in this eye-safe wavelength region.

In the area of photonics, the key spectrum analyzer performance parameters such as resolution, dynamic range, and tonal cross-talk will be evaluated. Spatial light modulators are the key component in the utilization of the concepts of optical signal processing for applications such as robotic vision and image identification. Real-time holographic writing techniques adaptable to a variety of spatial light modulators will be researched.

In the area of high-temperature superconductivity, thin films are exceedingly important since they are employed in a vast number of detector applications, such as the sensing of electromagnetic radiation, magnetic fields, and use in superconducting cavities for ultra-stable frequency applications in space clocks. Research will continue on the various high-temperature superconducting materials for thin film devices for space application.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Controls and guidance research and technology............................	5,260	6,700	6,700	5,600

OBJECTIVES AND STATUS

The objectives of the controls and guidance research and technology program are to develop and validate advanced controls algorithms for future complex spacecraft, e.g., large flexible antennas, segmented precision optical telescopes and interferometers, multi-instrument Earth observing platforms and space stations; to develop computational control tools for spacecraft control system design, analysis, and simulation, where modeling several hundred to thousands of states is required for an accurate description; to produce the technology for advanced sensors and actuators; to provide the basis for onboard guidance, navigation, and control techniques for future space transportation systems; and to define and develop methodologies for the design and validation of highly reliable advanced flight-crucial controllers.

During the past year algorithms, sensors and actuators were successfully tested in the large flexible vertical beam/antenna test facility at Marshall Space Flight Center for initial entry into our data base. Computational controls capability was further advanced with connecting topology systems (CONTOPS) maturity and the generation of a broad computational controls plan to help overcome the problem of solving large order systems. The fiber-optic gyro continues to show the initial promise of significantly reducing the cost, complexity and power demand through the successful demonstration of an eight-component optical chip.

In space transportation technology, progress was made in advancing our understanding of adaptive control for aerodynamically assisted orbit transfer aerobraking and aerocapture vehicles, precision guidance and navigation through planetary atmospheres from space to a safe touchdown area, and in designing and analyzing highly reliable fault- and damage-tolerant flight-crucial control systems.

BASIS OF FY 1990 ESTIMATE

Spacecraft controls algorithm testing and comparisons will begin using a new ground-based capability that provides for full-scale flight hardware testing. Research and testing will continue into the application of distributed optical sensors and magnetic actuators for lightweight flexible space structures in order to reduce the weight and number of these elements required for holding precise pointing and system shape.

Theoretical controls work in the field of precision structures will be expanded. The new thrust in computational controls will be matured to upgrade and expand the analytical tools and capability to analyze future large space systems. The successfully tested eight-component optical chip version fiber-optic gyro will be extended to a closed-loop demonstration using a proto-flight chip.

Guidance and controls technology for space transportation vehicles will continue to emphasize the development of algorithms for onboard real-time application and the development of advanced information processing architectures that are highly reliable, and fault and damage tolerant. Ada advantages and overhead burden will be investigated for control system use and deficiencies identified and documented for future correction. Emphasis will be placed on reducing operational avionics subsystem software generation, validation and support costs for new generation vehicles, such as the advanced launch system.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Human factors research and technology....	4,047	5,300	5,300	4,600

OBJECTIVES AND STATUS

The objectives of the space human factors research and technology program are to provide a technology base for intelligent operator interfaces, especially with highly automated systems, and to develop a new generation of high-performance space suits, gloves, end effectors and tools to meet the needs of new space activities and missions. These objectives include: development of guidelines for man-machine interfaces in spacecraft and work stations and computer-generated models of human performance, capabilities and limitations in weightless or partial gravity environments. The areas of human factors research emphasized are crew-station design and extravehicular activity (EVA),

Crew-station research focuses on: (1) development of human-computer interface technology and graphical presentations, including effective multidimensional visual and aural displays and applications of artificial intelligence to such displays; (2) development of a technology base for autonomous vision and other perceptual systems, virtual work station technology, and computational vision systems for space operations and maintenance; and (3) development of data bases related to human strength and motion and body positions in zero or partial gravity environments. Test and evaluation are emphasized in all three areas.

Extravehicular activity (EVA) research builds on progress in the design, testing, and operational evaluation of EVA suits and subsystems, including gloves, end effectors, and tools needed in EVA.

Crew-station research accomplishments have included evaluation of human performance in zero gravity with direct control devices, testing of a knowledge acquisition method for use in interfacing with artificial intelligence-based systems, and completion of a design tool for building graphical displays. Mathematical and computational models of human vision were used to develop models of human perception of spatial location and motion. Based on these models, a neural network for autonomous motion sensing was developed and evaluated. Work on an initial operating configuration of a virtual work station was completed so that testing could begin. The data base on human strength, motion and human performance effectiveness in zero gravity was updated.

EVA human factors research focused on development and test of a new, high-pressure EVA glove and glove materials; completion of the fabrication of a highly dexterous, multidegree-of-freedom mechanical end effector and its test in zero gravity; and completion of extensive tests of an electron end effector with built-in force feedback. Installation of a laser-based anthropometric mapping system at the Johnson Space Center was completed, and data collection began for range of motion and other body model variables. Electro-myographic recordings of astronauts' strength and physical workload (heart rate) began.

BASIS FOR FY 1990 ESTIMATE

Human factors research in FY 1990 for crew-station operations will include applications of laboratory test results on new display concepts to more realistic working environments on Space Station Freedom. Human information exchanges with "smart" embedded systems will be tested so that firm design guidelines may be issued. Virtual vision and three-dimensional aural work stations will be tested, and computational models of human visual and auditory systems will be validated in such tests. Coding of human vision, via mathematical models, will be verified by these and other tests. The role of the human as a teleoperator will be evaluated as a result of advances in robotic end-effector technology. It is expected that EVA glove fabrication and material forming techniques will be completed so that high-pressure EVA gloves can be produced for a wide variety of applications in a quicker, more effective manner. Mobility of the suited astronaut will be a major focus, so that appropriate methods to achieve human foot and shoe motion can be obtained for EVA activities.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Space flight research and technology.....	21,052	18,100	20,600	19,400

OBJECTIVES AND STATUS

The purpose of the space flight research and technology program is to flight test enabling technologies which require the actual space environment for validation. Flight data obtained from in-space research and experimentation will be used to validate and verify analytical models, prediction techniques, and ground test methods and facilities. This program encompasses the identification and definition of in-space flight experiments; the design, fabrication, and flight certification of experiments in preparation for space validation; and the development of unique, special purpose experiment hardware systems to facilitate technology validation in the space environment.

The space flight experiments being conducted within this program include the long duration exposure facility (LDEF), cryogenic fluid management flight experiment (CFMFE), orbiter experiments (OEX), light detection and ranging in-space technology experiment (LITE), and the identification and definition of space flight experiments which will provide solutions to critical space technology problems.

The LDEF has been in space since 1984, subjecting 57 experiments and the structure to erosion effects of the space environment. Preparations are being made for the return of LDEF on STS-32 in November 1989. Several experiments are being combined on the CFMFE to better understand the processes of storage, acquisition, and transfer of cryogenic fluids in the near zero-gravity space environment. Feasibility studies which define the experiments and determine technical feasibility of the flight concept will be concluded. Preliminary development of specific hardware unique to the success of the experiments (such as flowmeters and fail-safe valves) will begin. Four OEX research experiments which characterize the space transportation system orbiter aerodynamic/aerothermodynamic environment will begin the second of a planned six-flight series. Research experiments to measure the aerodynamic heating effects of tile gap geometry and tile surface catalytic properties, to provide space flight data on durable high-performance material concepts and to evaluate aerodynamically induced decelerations in the free molecular flow flight regime are in final development and will be integrated into Columbia (orbiter vehicle 102). LITE will develop and validate the capability of light detection and ranging (LIDAR) systems as an in-space research tool for measuring aerosols and better understanding the Earth's atmospheric phenomena. Final design will be completed and hardware fabrication initiated for this experiment in FY 1989. A workshop will be conducted to review critical space technology issues facing the U.S. in the immediate future. These problems/needs will be used to guide research and technology development in the industry, university and government ground-based facilities and will provide the basis for identifying future space technology experiments.

CHANGES FROM FY 1989 ESTIMATE

The space flight research and technology program reflects an increase of $2.5 million for cryogenic research, which was transferred from the propulsion research and technology program.

BASIS OF FY 1990 ESTIMATE

The LDEF will be retrieved in early FY 1990, and the 57 experiments and the structure will be distributed to the researchers and technologists for analysis and reporting of the flight results. The conceptual design study for the CFMFE will be initiated, and prototypes of the liquid hvdrogen and gaseous flow meters and the cryogenic relief valves will be completed. Ground testing of the prototype concepts will provide assurance that these concepts are viable for continued spacecraft development. Flight testing of the orbiter experiments will continue through FY 1990. Four additional flights will be completed, and analysis of the flight data will be an ongoing effort throughout the year. In FY 1990, fabrication of the remaining components for LITE will be completed and tested. Assembly of the components will be initiated in preparation for a launch readiness date of 1993. A group of space technology experiment definition studies will be initiated to provide solutions for critical technology problems/needs identified in the above-referenced workshop.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Systems analysis........................	5,376	6,900	6,900	6,900

OBJECTIVES AND STATUS

The objectives of the systems analysis program are to identify technology requirements for prescribed mission concepts and opportunities for enabling new and improved concepts, to integrate these into a comprehensive set of technology planning options, and to generate candidate plans to develop these technologies in a timely manner. Close coordination with the Offices of Space Flight, Space Science and Applications, Space Operations, Space Station, and Exploration and other users is maintained to ensure proper understanding of missions and to enable better prioritization of high-leverage technologies. This analysis program is directed at the systems-focused areas of space transportation, spacecraft, and large space systems and at emerging, new, mission concepts and mission-enabling technologies.

Spacecraft systems analysis is concentrated in five science and applications areas: astrophysics, space physics, Earth science, communications, and solar system exploration. In FY 1989, efforts are focused on the critical technologies associated with Earth science observations for understanding global change.

The space transportation systems analyses are focused on advanced Earth to orbit (ETO) vehicles, aeroassist space transfer vehicles (ASTV), and advanced space transportation systems conceptual design and analysis methods. The ETO studies include the technology to support an advanced heavy-lift launch vehicle, a second-generation reusable manned vehicle, and future low-cost space transportation systems. The ETO studies also include the definition of nonintrusive instrumentation and measurements applicable to the ascent and entry speed range of an ETO vehicle.

Three specific study areas constitute the large space systems analysis program: (1) systems analysis methods, to develop and maintain advanced analytic simulation/emulation computer-based capabilities for determining the operational characteristics of large space systems, predicting nominal and worst-case failure modes, and identifying critical system/subsystem interfaces; (2) future space systems, to address mission and system requirements and to identify their associated technology needs and trends; and (3) in-space research and technology experiments planning, using the shuttle, space station, and other space assets as laboratory facilities.

BASIS OF FY 1990 **ESTIMATE**

In FY 1990, many of the long-range efforts currently underway will be continued. These efforts will have substantial impact on the development of future CSTI and Pathfinder technology program elements, as well as on identifying thrusts for the research and technology base and the flight experiments programs. For spacecraft systems, the major focus will be to examine the technology planning options for more extensive future exploration of planet Earth. Within the astrophysics area, activities will center on the technology requirements for interferometric observatories across a range of wavelengths. Work will continue to synthesize the analytical techniques developed for past studies into a general purpose spacecraft systems analysis capability. Cooperative studies in solar system exploration and space physics will identify technology requirements €or key potential future missions.

The transportation systems analysis effort will continue the definition of key areas for lower cost transportation technologies and for technology growth in space transfer vehicles and advanced delivery systems to low Earth orbit. The analyses will focus on concepts and technology requirements for a possible lunar space transfer vehicle, a heavy-lift launch vehicle, and a shuttle-derived vehicle.

In large space systems, the transition of the systems analysis focus from the initial space station to an expanded mission perspective, including evolutionary space stations, lunar bases, and long-duration manned space trips, will be continued. The primary thrust of the extended perspective is to ensure that the research and technology base program is structured to enable and support the needs of these missions in the turn-of-the-century time frame. Additionally, the FY 1990 program will continue to include planning for the use of the space station as a facility to support research and technology.

In FY 1990, efforts will continue to address studies and analyses of opportunity-oriented technologies and their impact on enabling new mission/system capabilities. These studies will explore the potential applications of emerging, high-leverage technologies such as superconductivity, antimatter, and high-level machine learning to the formulation of new or improved system concepts.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
University space research...........	4,000	16,300	16,300	17,100

OBJECTIVES AND STATUS

The objective of the university space research program is to enhance and broaden the capabilities of the nation's engineering community to participate more effectively in the U.S. civil space program; it is an integral part of the strategy to rebuild the space research and technology base. The program responds to the need to remedy the decline in the availability of qualified space engineers by making a long-term commitment to universities aspiring to play a strong engineering role in the civil space program. The program utilizes technical advisors at NASA centers to foster collaborative arrangements, exchange of personnel, and the sharing of facilities between NASA and the universities. The program elements include the universitv space engineering research program that supports interdisciplinary research centers; the universitv investigators research vroaram, providing grants to individuals with outstanding credentials; and the universitv advanced space design program, which funds advanced systems study courses at the senior and graduate levels.

The universitv space engineering research program is designed to advance the traditional engineering disciplines applicable to space and bring together the knowledge, methodologies, and engineering tools needed to advance future space systems. The research centers promote the kind of multidisciplinary teamwork that systems technological problems demand and bring individuals from a wide range of engineering and scientific fields into a single research structure. These partnerships provide the universities with a broader charter for independent research and enable new mission concepts and ideas that might alter NASA's own visions of the civil space program. In April 1988, the Office of Aeronautics and Space Technology selected nine universities from a total of 115 proposers.

The objective of the universitv investigators research program is to sponsor individual research on highly innovative space technology concepts directed toward far-term mission use. The grants will be awarded to persons who have a demonstrated record of performance in generating and validating innovative concepts. Selection of grantees will be made through a competitive evaluation conducted by a peer review selection panel.

The objectives of the universitv advanced design program are to foster engineering design education in the universities and to supplement NASA's in-house efforts in advanced planning for space systems design. The study topics include potential missions which could be undertaken during a 20-30 year period, beginning with the space station initial operating configuration scheduled for the mid-1990's. The university advanced design program has been an effective mechanism for integrating the educational objectives of the university community with the advanced engineering design interest of NASA.

BASIS OF FY 1990 ESTIMATE

The FY 1990 program funding will continue the support to the nine incumbent centers of the university space engineering research program. Eminent researchers, selected in FY 1989, to participate in the university space investigators research program will continue to be funded and additional three-year grantees will be added. The total number of grants will reach a level of approximately 20 during FY 1990. The university advanced space design program will be expanded to approximately 34 universities.

BASIS OF FY 1990 FUNDING REQUIREMENTS

CIVIL SPACE TECHNOLOGY INITIATIVE (CSTI) PROGRAM

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Automation and robotics	25,332	25,900	25,900	25,900
Propulsion	23,600	46,700	36,100	37,400
Vehicle	15,000	28,000	13,300	36,000
Information technology	16,310	17,100	15,900	15,600
Large structures and control	21,158	25,100	19,500	18,900
High-capacity power	12,754	14,000	11,100	10,700
Total	114,154	156,800	121,800	144,500

OBJECTIVES AND STATUS

The CSTI, begun in FY 1988, was the first step in revitalizing national civil space capabilities for future Earth orbit missions. The CSTI will develop technologies to enable efficient, reliable access to Earth orbit, enhance operations in Earth orbit, and increase the effectiveness of science missions from low Earth orbit.

The objective of the automation and robotics program is to exploit the potential of artificial intelligence and telerobotics to increase the capability, flexibility, and safety of space and ground operations while decreasing associated costs. The automation and robotics elements consist of a sequence of evolutionary demonstrations using testbeds, mockups and shuttle and spacecraft operations in five core technology elements: sensing and perception, control execution, task planning and reasoning, operator interface, and systems architecture and integration. In FY 1989, the telerobot demonstration facility at the Jet Propulsion Laboratory will perform its first test in which the concept of traded control between a human operator and automatic control system within a task will be demonstrated. Also in FY 1989 first use of an expert system for monitoring the Space Shuttle's communications during flight was demonstrated. In addition, an autonomous system for thermal control will be demonstrated on a thermal control system testbed.

The objective of the propulsion program is to provide a validated design and analysis capability that can be applied to design and development of advanced propulsion systems for future low-cost reusable Earth-to-orbit vehicles and expendable or recoverable boosters. The program will validate methods and techniques developed from experiments with small laboratory scale models by designing, fabricating and testing full-scale models. The technology hardware will be highly instrumented and will be capable of varying operating conditions over a wide range, in order to provide a broad experimental data base with which to validate analytical codes and new design techniques. The booster technology program will investigate both solid-liquid hybrid boosters and pressure-fed bipropellant liquid boosters as alternate propulsion concepts for the space shuttle. Performance models will be generated and verified with data from static firings of test articles with increasing size. Initial design and analytical test validation at a component level has started.

In the vehicle area, the aeroassist flight experiment (AFE) will investigate critical design and environmental technologies applicable to the design of an aeroassisted space transfer vehicle (STV). Application of this technology has the potential for increasing the payload of an STV by a factor of two for transfer missions from the moon and geosynchronous orbit to low Earth orbit. Computational models and design tools have been developed to support the design on an STV, but ground facilities are inadequate to validate them. Flight experiments are necessary to provide this validation in the actual conditions associated with aerobraking. Specifically, the AFE will provide critical aerothermodynamic parameters including radiative heating levels, wake flow base heating levels, aerodynamics and control characteristics, and wall catalysis effects. Alternate thermal protection system materials which permit lightweight, flexible drag devices will be evaluated. A program requirements review has been completed and experiments selected.

The objective of the information technology program is to develop technologies that will enable active and passive detection and imaging of electromagnetic radiation and the development of advanced techniques, processes, and systems for high-speed/high-volume data storage and processing. These activities will involve discovery, invention and development of new techniques, materials, devices, components, and hardware systems. The sensor activities are concentrating on systems for the relatively unexplored submillimeter portion of the electromagnetic spectrum. The data activities are concentrating on technologies for a new generation of high-speed general flight processors and high-volume data handling and storage systems. New sensors operating at submillimeter wavelengths have been invented. Through participation in a multi-agency consortium, technology feasibility studies and demonstration of critical components for a read/write optical disk were completed.

The objective of the large structures and control element is to develop integrated structures and control technology to enable the development of large, flexible and high-precision structures to meet long-range requirements for complex multibody platforms, spacecraft, and large scientific instruments. Current design and testing methodologies will be inadequate to assure on-orbit performance for integrated structure and control systems at the scale and precision being considered. Part of the program is developing technologies for advanced orbiting scientific instruments which use large, extremely precise reflectors which must be lightweight and assembled and aligned on orbit. Systems studies have started, and early lightweight panels have been produced.

In the power area, the high-capacity power program objective is to develop the conversion system technology for a nuclear power system capable of supplying high-capacity power over a long period of time. The emphasis is on thermal-to-electric energy conversion, high-capacity heat rejection, and high-capacity power management and distribution subsystems. Technology demonstration tests have been completed for a free-piston Stirling engine. Advanced radiator concepts have been identified with one-half the mass of previous systems.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The CSTI program was reduced by a total of $35 million as a result of Congressional action on the FY 1989 budget. The reductions in the propulsion area include $8.6 million in Earth-to-orbit technology and $2.0 in booster technology. In the vehicle technology area, the aeroassist flight experiment was reduced by $14.7 million. The data: high rate/capacity program in the information technology area was reduced by $1.2 million. The control of flexible structures program under large structures and control was reduced by $5.6 million. In the power area, high-capacity power was reduced by $2.9 million.

BASIS OF FY 1990 ESTIMATE

The automation and robotics estimates are based on a planned sequence of evolutionary ground demonstrations scheduled to run through 1996. In FY 1990, expert system demonstrations include coordinated control of multiple subsystems, using the thermal control system testbed, and control of the shuttle environmental control systems during launch processing. Robotics demonstrations will include the addition of an automated planner and the introduction of short time delays to simulate remote location operations.

The Earth-to-orbit propulsion program will continue in FY 1990 to conduct technology tasks to verify high-pressure ignition, combustion performance and stability, and heat transfer and cooling. Design and fabrication of large-scale turbopumps and design of combustors will begin. Analytical modeling, code development and advanced design methodologies will continue to be developed. The space shuttle main engine technology testbed program will continue with emphasis on testing to help map the internal dynamic environments of that engine for use in verification of simulation codes. The booster technology activities will define technology programs in the areas of solid fuel burning characteristics, oxidizer injection concepts, and thrust termination. Combustor and tank pressurization technologies will continue to be studied in the pressure-fed liquid booster program

For the AFE program in FY 1990, final designs of the carrier, aerobrake and instruments will be completed. Preparations for critical design reviews prior to starting fabrication of hardware will be completed. Preliminary design reviews will be held for software systems, and critical design reviews will be held for ground support equipment.

The information technology activities in FY 1990 will be based on development of detectors in the 4- to 10-micron region using molecular beam epitaxy doping techniques, in the 30- to 300-micron region using blocked impurity band phenomena. In the submilleter wave region on quantum well local oscillator and superconducting tunnel junction mixers, backward wave oscillators and refrigerator technologies will also be investigated. The high rate/capacity data activities will continue on using four-processor, very high-speed, integrated circuit multiprocessors and will start development of a brassboard space flight optical disk recorder module. Preliminary design of on-board digital processors and correlators will be started.

In FY 1990, the large structures and control program will develop models and evaluate concepts for integrated structures and control systems. Future systems are expected to be large and flexible and possibly require extreme precision in configuration and control. Concepts of integrated pressure and active control will be investigated. Precision, segmented, lightweight reflectors will be fabricated; active vibration damping concepts will be developed; and precision panel control will be demonstrated on a single panel. A large truss concept will be fabricated to demonstrate structural precision feasibility.

High-capacity power activities in FY 1990 will contain a major contracted effort to develop technologies for the 1050°K Stirling space engine. Testing of components will be completed and design efforts to include these components in the engine will be started. Critical technology development and advanced radiator concepts will be pursued for both the engine and thermoelectric space power systems. Technology developments on radiation-hardened, high-temperature power management systems will be performed.

BASIS OF FY 1990 FUNDING REQUIREMENTS

PATHFINDER

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Surface exploration.....................	--	19,000	8,500	9,300
In-space operations.....................	--	43,000	15,000	15,600
Humans in space.........................	--	13,000	6,000	6,300
Space transfer..........................	--	10,000	5,500	6,100
Mission studies.........................	--	15,000	5,000	10,000
Total............................	--	100,000	40,000	47,300

OBJECTIVES AND STATUS

Pathfinder, begun in FY 1989, is a program through which NASA is developing a broad set of technologies that will enable decisions on potential future space missions. Pathfinder is a critical focused technology program that will strengthen the technological foundation of the civil space program and the nation's leadership to go forward with ambitious future solar system exploration missions. This program is organized into four technology areas: surface exploration, in-space operations, humans in space, and space transfer. In addition, mission studies will be conducted to support the detailed formulation of mission requirements and technology options.

The technologies included in the surface exploration program are related to the gathering of scientific knowledge and technical understanding at mission sites on the moon and Mars. The in-space operations program area will address critical technologies for in-space assembly and construction and the repair of massive and complex systems in Earth orbit and at lunar and Martian orbits, and for advanced planetary operations, such as in-situ resource utilization. The humans-in-space program area will address the technology for improving astronaut productivity, maintenance, and health, and minimal or no dependence on resupply of expendables. The space transfer program will support transportation to and from Earth orbit, the moon, Mars, and other planets. The mission studies program will formulate options and alternatives for potential future space initiatives in human exploration of the solar system.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The Pathfinder program was reduced by a total of $60.0 million as a result of Congressional action on the FY 1989 budget. This has resulted in a change in scope or deferred start-up of essentially all Pathfinder activities. The surface exploration area reflects reductions of $5.0 million in planetary rover technology; $1.0 million in sample acquisition, analysis and preservation; $1.5 million in surface power; and $3.0 million in photonics. In-space operations reductions include $20.0 million in SP-100; $4.0 million in cryogenic fluid depot efforts; $2.0 million in optical communications, deferring start up of this effort; $1.0 million in in-space assembly and construction, and deferral of resource processing pilot plant research ($1.0 million). The humans-in-space effort has been reduced by $7.0 million and restructured. The space transfer area was reduced by $2.0 million in chemical transfer propulsion; initiation of the cargo vehicle propulsion work has been deferred ($2.0 million); and the high energy aerobraking effort has been reduced by $0.5 million. The mission studies program was reduced by $10.0 million.

BASIS OF FY 1990 ESTIMATE

In the area of surface exploration technology, research will continue in planetary rover technologies, including surface mobility (both wheeled and legged), systems autonomy (including both ground control process automation and on-board software systems), on-board computation and guidance, including semiautonomous navigation and university research in mobile robotic research; in sample acquisition, analysis, and preservation, including compact multispectral sensors for in-situ sample analysis; in autonomous lander technologies, including both active and passive sensor systems, guidance, navigation and controls, including both precision landing and hazard avoidance during terminal descent, and low-mass, hazard-tolerant landing mechanisms; and in surface power systems, including advanced amorphous silicon photovoltaics cells and solar arrays and high-performance regenerative fuel cells.

In the area of in-space operations technology, research will continue in autonomous rendezvous and docking, including range and range rate active sensors with extended dynamic ranges and on-board guidance, navigation, and control to enable autonomous operations without ground-based human control; in-space assembly and construction, including structure component bonding and welding, and techniques for handling large, massive system elements; cryogenic fluid depot technologies, including microgravity cryogenic fluid analytic modeling, instrumentation to measure cryogen fluid parameters in zero gravity, and the development of a ground-based testbed for model validation; and space nuclear power, focused on refractory metal reactors, solid-state thermoelectric power conversion, and thermal management technologies such as heat pipes.

In the area of humans-in-space technology, research will continue in extravehicular activity suits, including highly-dexterous, high-pressure gloves, suit end effecters and tools, and portable life support systems, including thermal management systems, and carbon dioxide removal; space human factors, including human-automation-robotic systems, artificial environment human-machine interfaces, and development of basic human performance models for exploration missions; human performance, including defining requirements for human physiological considerations pertaining to space radiation, including both solar and cosmic radiation and microgravity effects, such as artificial gravity systems; and advanced life support systems, including bioregenerative life support, such as food production chambers.

In the area of space transfer technology, research will continue in cryogenic (hydrogen-oxygen) engines for space transfer vehicles and for ascent/descent propulsion. This includes a breadboard and technology for high throttleability, long life with multiple firings,,integrated engine diagnostics and controls, and designs for engine space-basing and -servicing. In research on a high-energy aerobraking for interplanetary mission applications, studies include computational fluid dynamic aerothermodynamic modeling for both the Earth and Mars atmospheric chemistries; thermal protection systems such as high-temperature ablative materials; guidance, navigation, and control, including both on-board optical navigation for planetary approach and autonomous on-board adaptive guidance to compensate for unanticipated variations in planetary atmospheric densities. In addition, high-energy aerobrake configurations will be defined for both the Earth and Mars and for robotic and piloted missions applications.

In the area of mission studies, case studies will be conducted of possible future missions of human exploration, including both evolutionary scenarios involving the utilization of in-situ resources at both the moon and Mars and expeditionary missions to Mars. These studies will encompass both mission design options, the effects of alternative scenarios on NASA infrastructure and systems, precursor mission requirements, and the technology needs of the exploration concepts.

BASIS OF FY 1990 FUNDING REQUIREMENT

IN-SPACE EXPERIMENTS TECHNOLOGY PROGRAM

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
In-space experiments technology program............................	--	--	--	16,200

OBJECTIVES AND STATUS

The purpose of the in-space technology experiments program (IN-STEP) is to provide validated, advanced space technologies to the designers for improving the effectiveness and efficiency of current space systems and to provide major advancements for future space systems. For the past few years, highly innovative technology concepts have been identified in the research and technology base program that require testing or validation in the actual space environment in order to reduce the risk to the potential users and to increase the rate of transfer of advanced technologies into future space missions. Examples of these technologies include: behavior of fluids in the microgravity environment which is essential for the design of advanced thermal management systems, power systems, propulsion systems, and environmental control and life control systems; use of robotics in space construction, servicing, and other in-space operations; and environmental effects on materials from long-term exposure to the space environment.

This is a focused technology program that will coalesce many unique space technology concepts into defined flight experiments and will sponsor the hardware development of these experiments, so that these innovative technologies can be validated in the space environment for use in future space system designs. This program will concentrate on experiments performed primarily on the Shuttle mid-deck or in "get-away special" cans. Many will serve as precursors to experiments that will take advantage of the Space Station Freedom facilities available later in the decade. The three major elements of this program are the NASA in-space experiments, industry/university experiments, and the international experiments.

For example, included in these advanced technology experiments are several concepts generated at the NASA research and development centers such as the arcjet experiment, the space station structural characterization experiment (SSSCE), the debris collision sensor (DCS) experiment, and several innovative concepts currently in the definition phase. The arcjet experiment is an advanced reaction controller which will provide communications satellites with the capability of remaining on orbit for longer period of time, saving launch weight and improving efficiency. The SSSCE will provide space structure instrumentation on the space station, which will allow it to be used as a research facility, and will validate and upgrade current analytical modeling and prediction techniques for large space structures. The DCS experiment will validate a sensor concept which measures and identifies small debris in low Earth orbit that could be detrimental to spacecraft, space structures, and the safety of man. This debris is currently undetectable by ground radars and telescopes or current space sensors. These three experiments are in the conceptual design phase in preparation for space flight experiments.

The industry and university technology experiments program has identified over 200 innovative space technology concepts generated through U.S. industry and university research. Thirty-six of the most critical technologies were selected for the definition of in-space flight experiments. Five experiments were developed adequately to initiate conceptual design studies in preparation for design, fabrication, and ground certification. Typical examples of these five experiments are the tank pressure control (TPC) and the investigation of spacecraft glow experiments. The TPC experiment will validate predicted mixing and thermal stratification characteristics of fluids in a zero-gravity environment influenced by jet-induced flow. Data collected during flight may significantly reduce cost and complexity of fluid tanks in future spacecraft. The glow experiment will study the causes and effects of ram-induced radiation observed about certain materials when subjected to the space environment. A better understanding of the glow phenomena may reduce erosion of space structures and may provide an effective means of identifying/characterizing future spacecraft.

The international technology experiments program combines unique U.S. technology concepts with particular foreign hardware to capitalize on special flight opportunities. Typical of these experiments is the telerobotic intelligent interface flight experiment (TRIIFEX), which utilizes the German manipulator hardware developed and manifested on the Spacelab D-2 mission (STS-52, December 1991) to validate an advanced force-feedback controller. The data received from this experiment will provide validation of telerobotic concepts which may be used to construct future space structures.

BASIS OF FY 1990 ESTIMATE

The FY 1990 funding will provide for the continued development of the selected space technology experiments for flight validation on the Space Shuttle and expendable launch vehicles in FY 1991 through FY 1993. Hardware design and fabrication will be initiated on the arcjet, DCS, TRIIFFX, and the five flight experiments under development in the industry and university program. Research instrumentation will begin to be developed for incorporation on Space Station Freedom in preparation for its utilization as a space research facility. Conceptual design studies for key flight experiments, which will provide solutions to critical technology problems and which are currently being defined in the industry/university program, will be initiated in preparation for in-space technology experiments on launch vehicles during FY 1994 through FY 1996.

SAFETY RELIABILITY
AND QUALITY
ASSURANCE

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

SUMMARY OF RESOURCE REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Safety, Reliability, Maintainability and Quality Assurance..................	14.100	22.400	22.400	23.300	RD-15-1
Distribution of Program Amount Bv Installation					
Johnson Space Center....................	2,237	900	2,600	2,500	
Kennedy Space Center....................	300	100	300	500	
Goddard Space Flight Center..............	621	1,188	1,488	1,900	
Jet Propulsion Laboratory................	2,312	2,250	2,860	3,500	
Ames Research Center....................	420	450	450	500	
Langley Research Center..................	2,002	1,293	3,200	3,800	
Lewis Research Center...................	1,381	1,500	1,500	2,000	
Marshall Space Flight Center.............	1,210	425	1,575	1,800	
Headquarters...........................	3,617	14.294	8.427	6.800	
Total................................	14.100	22.400	22.400	23.300	

PROGRAM OBJECTIVES

The Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) program supports NASA's overall goals through activities in safety, reliability, quality assurance, maintainability, systems engineering, and program practices including independent assessment activities which reduce program risk. Specific objectives of the program are to:

- Identify and provide independent assessment of issues that have potential impact on mission success.

- Support in-depth reviews, studies, and analyses of issues and problems for readiness to launch.

- Conduct major tests and provide a viable problem reporting, corrective action, and trend analysis program throughout NASA.

- Perform radiation characterization on integrated circuits and complement the Air Force program for testing on-orbit radiation effects.

- Upgrade existing software standards, guidebooks, and training; and identify software management product assurance and automated work stations.

- Develop product assurance methodology for procuring reliable, custom large scale integrated (LSI) and very large scale integrated (VLSI) circuit components.

- Upgrade technology and emphasize the safety, reliability and performance of NASA's aerospace battery power systems.

- Plan, document, and establish policy for a NASA-wide SRM&QA Information System.

- Increase the safety of high hazard operations and develop safety risk management policy and guidance for all NASA programs.

- Support industrial, aviation, fire protection, and ground operations safety activities.

- Provide policies, procedures, and surveillance for all agency safety, quality, maintainability, and reliability activities.

- Develop and promulgate risk management and human factors safety programs that augment existing System Safety initiatives.

PROGRAM STATUS

In concert with the NASA Centers and industry, efforts continue in the area of materials treatments and processes; integrated circuit product assurance; microcircuit radiation effects evaluation, aerospace and system safety related matters; and other areas in support of NASA-wide programs. The Non-Destructive Evaluation (NDE) Program places special emphasis on developing NDE techniques for assessing the quality of Solid Rocket Motors (SRM's). Development of qualitative and quantitative inspection and quality control techniques for microcircuits and semiconductors is being promoted. The Software Management and Assurance

Program will continue to deveiop standards, specialized training, distributed software, corporate memory data bases, and guidebooks to facilitate improved software business practices. The Maintainability Program is now well established and continues to work with NASA programs on appropriate issues.

Previously, in response to the findings and recommendations contained in the Report of the Presidential Commission on the Space Shuttle Challenger Accident (Rogers' Commission), a system was developed to address the reporting and documentation of significant problems, assessment of problem resolutions, and analysis of trends. Appropriate goals have been established and continue to measure the effectiveness of this new system.

The NASA Safety Program is focused on developing specific programmatic system safety management procedures and providing independent system safety review at Headquarters. The program will conduct assessments of and develop requirements for hazardous systems such as: radio frequency interference; ionizing radiation; toxic chemicals and propellants; and propulsion, ordnance and electrical systems. The assessment of Space Transportation System (STS) System Safety Management procedures and the development of specific programmatic systems safety procedures will be completed in FY 1989. System safety management procedures for Level I independent safety reviews, hazard analyses procedures and prioritization methods, system safety methodology development for flight critical software, and safety risk acceptance criteria recommendations are underway.

BASIS FOR FY 1990 ESTIMATES

In FY 1990, the SRM&QA program will continue to provide leadership to all operational, programmatic, and institutional activities of the Agency. The key ingredient of this leadership is the continued integration of top level SRM&QA policies, procedures, and standards into each NASA program area. In the past year, key reliability requirements have been revised and expanded and deficiencies identified. Preferred techniques for implementing these new requirements will now be developed and additional research will be initiated to develop the technology to eliminate the deficiencies. These techniques will ensure that the most current and effective methods in reliability engineering will be applied to all NASA programs thus optimizing reliability, reducing risk, and enhancing mission effectiveness, The NDE measuremect assurance program will continue to provide state-of-the-art, quantitative, advanced inspection techniques for solid rocket motors, composites, and ceramics, The program will also explore advanced inspection techniques such as microfocus x-ray, fiber optics, acoustic emission, computer tomography, and laser thermography.

The Systems Assessment program will continue to provide independent "second look" assessments of major NSTS flight hardware issues.

UNIVERSITY
PROGRAMS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

UNIVERSITY SPACE SCIENCE & TECHNOLOGY
ACADEMIC PROGRAMS

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
University affairs	(12,100)	(12,600)	(12,600)	15,900	RD 16-2
Minority university research	(9,500)	(9,700)	(9,700)	14,100	RD 16-7
Space grant college and fellowship	--	--	--	5.000	RD 16-13
Total	(21,600)	(22.300)	(22.300)	35.000	

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

UNIVERSITY SPACE SCIENCE AND TECHNOLOGY ACADEMIC PROGRAMS — **UNIVERSITY AFFAIRS PROGRAMS**

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Graduate student researchers	(4,800)	(5,000)	(5,000)	6,800	RD 16-4
Summer faculty fellowships	(2,400)	(2,500)	(2,500)	3,800	RD 16-4
Innovative research	(2,300)	(2,400)	(2,400)	2,500	RD 16-5
Space applications	(2,600)	(2,700)	(2,700)	2,800	RD 16-6
Total	(12,100)	(12,600)	(12,600)	15,900	

Distribution of Program Amount by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Ames Research Center	(748)	(788)	(788)	1,023
Goddard Space Flight Center	(677)	(717)	(717)	952
Jet Propulsion Laboratory	(632)	(672)	(672)	907
Johnson Space Center	(659)	(699)	(699)	934
Kennedy Space Center	(140)	(180)	(180)	435
Langley Research Center	(859)	(860)	(860)	1,095
Lewis Research Center	(638)	(678)	(678)	928
Marshall Space Flight Center	(655)	(695)	(695)	930
Stennis Space Center	(36)	(54)	(54)	509
Headquarters	(7,056)	(7,257)	(7,257)	8,187
Total	(12,100)	(12,600)	(12,600)	15,900

UNIVERSITY SPACE SCIENCE AND TECHNOLOGY ACADEMIC PROGRAMS

UNIVERSITY AFFAIRS PROGRAMS

PROGRAM OBJECTIVE AND JUSTIFICATION

This program plus the Minority University Research program is proposed as a new budget line item this year in order to focus and enhance the resources and management devoted to university programs. FY 1990 funding will provide for continuation of agency-wide university and minority university programs which were previously budgeted in other NASA programs. As mandated in NASA's FY 1988 Authorization Act, funding is also provided for the National Space Grant College and Fellowship program.

The goal of the NASA University Affairs program is to create and maintain strong and mutually productive working relationships with the Nation's university community. In order to accomplish this goal the Office of External Relations and the Office of Space Science and Applications manage certain unique university programs that are agency-wide in scope and interest but are not within the direct responsibility of NASA program offices.

The specific objectives of the University Affairs program are:

To significantly increase the number of highly trained scientists and engineers in aeronautics, space science, space applications and space technology to meet the continuing needs of the national aerospace effort.

To facilitate the direct interaction, further the professional knowledge and stimulate the exchange of ideas between university faculty members and NASA scientists and engineers.

To support innovative research at U.S. institutions of higher learning, research which is in the formulative or embryonic stage and which would appear to have significant potential to advance space science and applications programs.

To provide for the development and use of a core, long-term U.S. national university capability to conduct multiyear, Earth science discipline-oriented applied research and remote sensing.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Graduate student researchers.............	(4,800)	(5,000)	(5,000)	6,800

OBJECTIVES AND STATUS

The Graduate Student Researchers Program, initiated in 1980, provides graduate fellowships nationwide to post-baccalaureate U.S. citizens to conduct thesis research at a NASA Center or to carry out a program of study or research at their home institution. From 1980-1984, approximately 40 new awards were made each year. In 1985, NASA doubled the size of the program to make 80 new awards each year. Awards are made to graduate students for a maximum of three years. On an annual basis, NASA supports approximately 250 graduate students pursuing the masters or doctorate degrees.

BASIS FOR FY 1990 ESTIMATE

The FY 1990 funding will allow for the Continuation of the current program. The additional funding in FY 1990 will provide for the initiation of the Graduate Student Researchers program at the Kennedy Space Center and the John C. Stennis Space Center, as well as increasing the number of annual awards available yearly at each NASA center. In addition, student stipends will be increased as they have remained constant since 1985.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Summer faculty fellowships..............	(2,400)	(2,500)	(2,500)	3,800

OBJECTIVES AND STATUS

The NASA Summer Faculty Fellowship program has completed 25 years of operation. This program has provided highly beneficial opportunities for engineering and science faculty throughout the United States by allowing participation in NASA research. This program has contributed significantly to the improvement of both undergraduate and graduate education, and directly benefited NASA, universities, faculty, students, and the Nation.

The Summer Faculty Fellowship program enables university faculty to spend 10 weeks working directly with scientists and engineers at NASA Field Centers on problems of mutual interest. Participants must have a minimum of two years teaching experience and must be citizens of the United States. The program is designed to further the professional knowledge of faculty members, to stimulate an exchange of ideas between participants and NASA, and to enrich the research and teaching activities of the participants' home institutions. This activity is operated cooperatively with the American Society for Engineering Education (ASEE).

Approximately 200-250 university faculty are supported annually for ten weeks. Evaluations conducted by ASEE of the program indicate that approximately 30-40 percent of the participating faculty subsequently receive NASA research grants or contracts.

BASIS FOR FY 1990 ESTIMATE

The FY 1990 funding level is required to maintain the current program, allow initiation of the Summer Faculty Fellowship program at the John C. Stennis Space Center, increase the stipends which have remained constant for the past three years, and increase the available number of annual awards at each NASA center.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Innovative research..................	(2,300)	(2,400)	(2,400)	2,500

OBJECTIVES AND STATUS

Over the past decade, it has become increasingly apparent that a key to the future health and well-being of the space science and applications program lies in having the capacity to explore new ideas or novel technical approaches to research. In response to this need, the Innovative Research program was established within the Office of Space Science and Applications to support research which, while still in its formulative stage, has already demonstrated potential for significant advances for space science and application programs. The program is intended to provide a mechanism for the funding of scientifically sound proposals which might not be funded through normal channels either because of their interdisciplinary nature or because they are, in some sense, speculative or risky. The long-term goal is to help the new ideas mature to a state of acceptability within particular science discipline resources.

The Innovative Research program was initiated in 1980, with announcements of the availability of funds and NASA's interest in receiving proposals for this type of research having been issued in 1980, 1982, 1985, and 1988. Emphasis in the program has been on the support of innovative research at universities and colleges. The primary criterion for inclusion in the program has been the originality and promise for innovation of the work being proposed. Over the past several years a number of major technical advances have resulted from research supported by this program such as the development of new infrared detector technology by the University of California-Berkeley using non standard scientific approaches.

BASIS FOR FY 1990 ESTIMATE

As a result of the 1988 review cycle, 20 investigations at 20 institutions were selected with levels of support ranging between $55,000 and $250,000 per year. Awards were for one to three-year periods to allow adequate time for the development and demonstration of the validity of new ideas. The requested FY 1990 funding will provide for continuation of the current program and allow a few additional awards to be initiated.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Space applications......................	(2,600)	(2,700)	(2,700)	2,800

OBJECTIVES **AND** STATUS

The objectives of the Space Applications program are to provide, through university grants, for the development and use of a core U.S. national university capability to conduct multiyear, discipline oriented basic and applied research in space applications; and to establish and maintain multidisciplinary remote sensing techniques and the use of those techniques in furthering the understanding of Earth sciences. This program has been the major impetus for the development of a geographically distributed network of universities which now comprise the prime source of the research and the development of techniques designed to use remote sensing data in the study of global Earth science processes and Earth resources management.

BASIS FOR FY 1990 ESTIMATE

This program has achieved considerable success in developing a community of researchers knowledgeable in remote sensing science and in contributing toward the overall evolving maturity of spaceborne remote sensing. In FY 1990, the Space Applications program will focus on working with the university community to prepare for the space-based remote sensing of the Earth in the Space Station era.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

UNIVERSITY SPACE SCIENCE AND TECHNOLOGY ACADEMIC PROGRAMS

MINORITY UNIVERSITY RESEARCH PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Historically black colleges and universities	(7,500)	(7,700)	(7,700)	8,900	RD 16-9
Other minority universities	--	--	--	2,000	RD 16-10
Graduate student researchers program (underrepresented minority focus)	(2,000)	(2,000)	(2,000)	2,200	RD 16-11
Undergraduate student researchers program (underrepresented minority focus)	--	--	--	1,000	RD 16-12
Total	(9,500)	(9,700)	(9,700)	14,100	

Distribution of Program Amount By Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center	(320)	(420)	(420)	1,420
Kennedy Space Center	(250)	(250)	(250)	550
Goddard Space Flight Center	(1,204)	(1,204)	(1,204)	1,204
Jet Propulsion Laboratory	(--)	(350)	(350)	850
Ames Research Center	(202)	(224)	(224)	224
Stennis Space Center	(--)	(334)	(334)	314
Langley Research Center	(1,536)	(1,308)	(1,308)	2,368
Marshall Space Flight Center	(1,743)	(1,515)	(1,515)	1,775
Headquarters	(3,928)	(3,778)	(3,778)	5,077
Lewis Research Center	(317)	(317)	(317)	318
Total	(9,500)	(9,700)	(9,700)	14,100

UNIVERSITY SPACE SCIENCE AND TECHNOLOGY ACADEMIC PROGRAMS

MINORITY UNIVERSITY RESEARCH PROGRAM

PROGRAM OBJECTIVE AND JUSTIFICATION

The goals of the NASA Minority University Research program are to continue to implement aggressively the initiative €or Historically Black Colleges and Universities (HBCUs); develop closer relationships with minority universities other than HBCU's; maintain the Graduate Student Researchers program (underrepresented minority focus); and introduce an Undergraduate Researchers program (underrepresented minority focus). The Office of Equal Opportunity Programs has the responsibility for the management of these programs.

NASA's HBCU initiative is mandated by Executive Order 12320 (issued September 1981) which requires Federal agencies to increase significantly the involvement of HBCUs in Federally sponsored programs. NASA has implemented this initiative primarily through research and training grants. In FY 1990, NASA is proposing the establishment of HBCU-Space Science and Engineering Centers of Excellence (SSECE) in order to be further responsive to the spirit of Executive Order 12320 and to help strengthen the research capabilities of selected HBCUs.

In FY 1985, Congress, through the Reports of the House Committee on Science and Technology, the House Authorization Committee, the House and Senate Appropriations Committees and the Senate Committee on Commerce, Science, and Transportation, instructed NASA to also build closer relationships with other universities that educate large numbers of minority students who are underrepresented in science and engineering, while not diminishing the agency's efforts towards the HBCUs. NASA made a commitment to Congress to: (1) establish or expand our research and development (R&D) relationship with a few selected universities; (2) encourage principal investigators to add underrepresented minorities to their research grants; and (3) increase participation of universities with substantial numbers of underrepresented minorities in our co-op programs, faculty summer assignments, graduate student researchers, post-doctoral fellowships and other programs.

NASA's proposed introduction of a Undergraduate Researchers Program (underrepresented minority focus) is based on the recommendations of NASA principal investigators. The concept also is consistent with the recommendations of the national Task Force on Women, Minorities, and the Handicapped in Science and Technology which urged the establishment of a variety of scholarships, fellowships, hands-on research opportunities, and other support to capture and develop these groups. It has become increasingly apparent that many promising minority high school graduates with excellent grade point average and scholastic achievement test scores enter college, but do not elect science and engineering fields. Further, many of the minority science and engineering students who succeed at the undergraduate level and who have the ability to do graduate level research, never consider research as a career option. NASA principal investigators report that very few graduate-level minorities are available; however, they can find minorities at the undergraduate level and encourage them to pursue graduate degrees. Thus, the objective of this program is to build a pipeline of undergraduate minority students and ensure increased numbers for graduate studies.

In all of the above programs, NASA's ultimate goals are to encourage strong research focus and alliances between HBCUs, other minority universities, majority research universities, industry, and other Federal R&D agencies; and to help develop the resource pool of future talent that will be needed by this agency, those institutions and the Nation.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Historically black colleges and universities...........................	(7,500)	(7,700)	(7,700)	8,900

OBJECTIVES AND STATUS

The objectives of the Historically Black Colleges and Universities (HBCU) program are to increase significantly HBCU participation in NASA sponsored programs; increase and strengthen their research infrastructure, curriculas and faculty capabilities; help develop a cadre of minority undergraduate and graduate science and engineering researchers at the HBCUs; and involve private sector institutions in the NASA/HBCU initiatives.

NASA will continue to sponsor, promote and encourage individual and team research and training grant projects and programs which include the participation of undergraduate and graduate students. In addition, NASA is proposing the establishment of two HBCU-Space Science and Engineering Centers of Excellence (SSECE) to upgrade scientific and technical research and development capabilities of a few of the most productive HBCUs. This initiative will expedite the strengthening of the institutions' research infrastructure and curricula, increase the number of minority faculty and students engaged in meritorious scientific research, and help the universities become renowned as major centers of excellence in their chosen areas.

In FY 1988, 31 HBCUs participated in NASA sponsored programs; and they were the recipients of 78 research and development and 22 training grant awards. A total of 24 faculty fellows, 232 graduate and 465 undergraduate students participated in the NASA/HBCU efforts. The HBCU program is funded by this program and other awards that may emanate from programs and installations during the fiscal year.

BASIS OF FY 1990 ESTIMATE

In FY 1990, in addition to continued funding for HBCUs, NASA plans to select one or two HBCU-SSECEs. At least a five year commitment to each center is anticipated. A comprehensive annual evaluation of both center program efforts will be conducted to determine the effect on constituent users; and the results will be utilized for program modifications for subsequent funding periods or for decisions concerning further expansion.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Other minority universities...............	--	--	--	2,000

OBJECTIVES AND STATUS

NASA will establish and/or expand its relationships with universities with significant populations of minorities who are traditionally underrepresented in science and engineering. It is anticipated that these other universities will be selected on the basis of a combination of factors, such as science and engineering curricula and accreditation, research capabilities, and significant numbers of underrepresented minority students and faculty. These other universities will be encouraged to increase their participation in NASA's research and technology, educational opportunities, and services.

BASIS OF FY 1990 ESTIMATE

FY 1990 funding will provide initial research grants for a few selected universities other than HBCUs to expedite the strengthening of their research infrastructure and curricula and to increase their minority faculty and students engaged in meritorious scientific research.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Graduate student researchers program..... (underrepresented minority focus)	(2,000)	(2,000)	(2,000)	2,200

OBJECTIVES AND STATUS

The objectives of this program are to enhance the development of underrepresented minority talent in an effective way so as to utilize the potential of this Nation's diverse citizenry; and to increase the size of the resource pool of research skills that will be needed to meet aerospace and other technological objectives of the future. Principal investigators who have NASA research grants, and a need for further student involvement, will be encouraged to seek out talented underrepresented minority students and involve them in their NASA research projects. The underrepresented minorities who are the special focus of this program are Blacks, Hispanics, American Indians and Pacific Islanders. They must be enrolled in masters or doctoral programs in engineering, physics, mathematics, computer science, biology, or other disciplines of interest to NASA in aeronautics, space and life sciences.

In FY 1988, the second year of the program, an additional 48 underrepresented minority students were selected to make a total of 108 participants in the program. These included 51 Blacks, 47 Hispanics, 6 American Indians and 4 Pacific Islanders.

BASIS OF FY 1990 ESTIMATE

The funds provided in FY 1990 will be used to continue the current program and allow for an increase in students stipends.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Undergraduate student researchers program (underrepresented minority focus)	--	--	--	**1,000**

OBJECTIVES AND STATUS

This new program will identify freshman-level, high potential, underrepresented minority students attending universities and majoring in science and/or engineering; and will serve as a feeder to the Graduate Student Researchers program (underrepresented minority focus). Identified students will receive tuition support; will be monitored, tutored, and nurtured; and by their junior year, will become research assistants working with principal investigators at their universities on NASA sponsored research. The primary objective is to encourage talented underrepresented minorities to choose, as a career option, graduate level studies in science and engineering.

BASIS OF FY 1990 ESTIMATE

The funds provided in FY 1990 will be used to initiate the undergraduate student researchers program.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

UNIVERSITY SPACE SCIENCE & TECHNOLOGY ACADEMIC PROGRAMS

SPACE GRANT COLLEGE AND FELLOWSHIP PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Space grant college and fellowship.......				*5,000*
Distribution of Program Amount bv Installation				
Headquarters............................				5,000
Total.................................				5.000

UNIVERSITY SPACE SCIENCE AND TECHNOLOGY PROGRAMS

SPACE GRANT COLLEGE AND FELLOWSHIP PROGRAM

PROGRAM OBJECTIVES & JUSTIFICATION

Enacted in NASA's FY 1988 Authorization Act (P.L. 100-47), the National Space Grant College and Fellowship program was designed to broaden the base and enhance the capabilities of the university network capable of contributing, through research, education and public service, to the increased utilization of space and its resources.

The objectives of the program are to:

(1) Increase the understanding, assessment, development, and utilization of space resources by promoting a strong educational base, responsive research and training activities, and broad and prompt dissemination of knowledge and techniques;

(2) Utilize the abilities and talents of the universities of the Nation to support and contribute to the exploration and development of the resources and opportunities afforded by the space environment:

(3) Encourage and support the existence of interdisciplinary and multidisciplinary programs of space research within the university community of the Nation, to engage in integrated activities of training, research and public service, to have cooperative programs with industry, and to be coordinated with the overall program of the National Aeronautics and Space Administration;

(4) Encourage and support the existence of consortia, made up of university and industry members, to advance the exploration and development of space resources in cases in which national objectives can be better fulfilled than through the program of single universities;

(5) Encourage and support Federal funding for graduate fellowships in fields related to space; and

(6) Support activities in colleges and universities generally for the purpose of creating and operating a network of institutional programs that will enhance achievements resulting from efforts under this title.

OBJECTIVES AND STATUS

The Space Grant College and Fellowship program is composed of three complementary elements. Designated "space grant colleges/consortia" form the centerpiece. The space grant designation will recognize preeminent institutions which are substantially involved in a broad spectrum of NASA research, offer advanced study in aerospace fields, and are significantly involved in related public service. Designation will be based on the institution's plan to network with the broader higher education community, establish cooperative relationships with industry and develop innovative public outreach. Designated schools will be initially funded at $150,000 and are expected to provide matching funds. The second element, the grant program, enables all universities to participate in the Space Grant Program. Grants will be available to meet unique aerospace challenges or to develop institutional capability. The third element, the Fellowship program, will provide a means to meet the critical needs for well trained aerospace engineers and scientists by providing universities selected in the previous two elements, funding for undergraduate and graduate fellowships.

BASIS FOR FY 1990 ESTIMATE

Funding in FY 1990 will provide for phasing in the elements of the Space Grant College and Fellowship program. Through a merit review process, universities will be selected and designated as "Space Grant Universities/Consortia." The Space Grant program will be implemented to begin to broaden the base of universities involved in space'related research. The fellowship program will also be implemented in FY 1990.

·CKING AND DATA
·NCED SYSTEMS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE OPERATIONS

TRACKING AND DATA ADVANCED SYSTEMS

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Advanced systems........................	17,900	18.800	18.800	19.900	RD 17-2
Total................................	17,900	18,800	18.800	19.900	

Distribution of Program Amounts by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Goddard Space Flight Center..............	5,400	5,800	5,800	6,200
Jet Propulsion Laboratory................	12,216	13,000	13,000	13,700
Headquarters............................	284	---	---	---
Total................................	17.900	18.800	18.800	19.900

BASIS OF FY 1990 FUNDING REQUIREMENTS

ADVANCED SYSTEMS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Advanced systems........................	17,900	18,800	18,800	19,900

OBJECTIVES AND STATUS

The objective of the Advanced Systems program is to study and develop new higher performance tracking and data handling capabilities which will address planned future mission requirements and will provide improved cost-effectiveness and reliability for overall support of the total mission mix.

This activity is a small but vital part of the total Office of Space Operations program. Advanced Systems programs continue to focus on assessing and employing technological advances in telecommunications, electronic microcircuitry, and computer sciences. Such effort is essential for the cost-effective application of new technology and for planning future mission support capabilities. Ongoing work includes the investigation of the total data transfer and processing needs of upcoming missions and studies of ground systems and telecommunication links to determine design approaches, and overall tradeoffs for the lowest life cycle costs to support future space missions.

BASIS FOR FY 1990 ESTIMATE

Activities planned for FY 1990 include efforts to obtain location accuracies at the decimeter level for Earth-orbiting spacecraft, which wocld make possible a new class of high precision Earth observatory missions on the Space Shuttle, Space Station, and on free-flying spacecraft. Work will continue on the development of extremely precise radiometric techniques for determining angular direction of future planetary missions to an accuracy of five nano-radians. Such improvements typically lead to improved spacecraft navigation and the conduct of science experiments not previously possible. Studies will continue on ground-based navigation strategies, analyses, and demonstrations for Galileo, Ulysses, and Mars Observer.

Efforts to improve communications between the ground and spacecraft will continue in such areas as the use of millimeter wave frequencies on large diameter antennas; development of more efficient transmitters and highly reliable, low noise telemetry receivers; development of a K-Band terminal for TDRSS-user spacecraft; and, antenna feed systems capable of multiple frequency operation, including millimeter waves. Such improvements in space-to-ground communications can benefit future missions by increasing the amount and quality of the data returned. Optical tracking and communications technology to meet telecommunications needs in the decades ahead will also be investigated both for cost-performance advantages over microwave technology and for potential in space data relay applications.

Future high-rate image data storage and processing requirements for Earth-orbital missions are expected to increase from a current peak use of 85 megabits per second to 300 megabits per second in the Space Station era. These requirements result from high-resolution sensors, such as multispectral scanners and synthetic aperture radars, which will be transmitting more data than previous instruments. New techniques and systems will be studied and developed for the storage, processing, and transmission of these high data rates. These studies and developments include new techniques for signal coding and decoding, optical disk buffering and storage, automated distribution and processing of high volume data, improved man-machine interfaces, high-speed modulators/demodulators, and a communications network using an optimal mix of fiber optics, satellites, and local area networks to distribute data to processing centers and users.

Investigations will continue on developing more efficient mission operations control center facilities and providing for the necessary real-time interaction between the ground-based experimenters and their spaceborne experiments. Other investigations are being carried out in the area of expert systems applications, greater use of distributed command terminals, and the performance of orbit and attitude computations onboard the spacecraft.

SPACE FLIGHT
CONTROL AND DATA
COMMUNICATIONS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1990 ESTIMATES

GENERAL STATEMENT

The objective of the National Aeronautics and Space Administration program of space flight, control and data communications is to provide for the operational activities of the Space Transportation System and tracking and communication system support to all NASA flight projects. This objective is achieved through the following elements:

SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY: A program to provide a fully capable fleet of Space Shuttle orbiters, mcin engines, launch site and mission operations control requirements, spares inventory, production tooling, and related supporting activities.

SPACE TRANSPORTATION OPERATIONS: A program to provide the standard operational support services for the Space Shuttle and the expendable launch vehicles. Within Shuttle operations, external tank and solid rocket booster flight hardware is produced; operational spare hardware is provisioned, overhauled and repaired; and manpower, propellants, and other materials are furnished to conduct both flight and ground (launch and landing) operations.

SPACE AND GROUND NETWORK. COMMUNICATIONS AND DATA SYSTEMS: A program to provide vital tracking, telemetry, command, and data acquisition support to meet the requirements of all NASA flight projects using ground-based and satellite (Tracking and Data Relay Satellite System) components.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1990 ESTIMATES

	1988 Actual	1989 Revised Budget	1989 Current Estimate	1990 Budget Estimate
		(Millions of Dollars)		
Shuttle production and operational capability	1092.7	1400.5	1128.2	1305.3
Space transportation operations	1833.6	2405.4	2390.7	2732.2
Space and ground networks, commun cation and data systems	879.4	1035.3	945.3	1102.1
Total	3805.7	4841.2	4464.2	5139.6

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

For necessary expenses, not otherwise provided for; in support of space flight, spacecraft mntml and communications activities of tbe National Aeronautics and Space Administration, including operations, production, services, minor construction, maintenance, repair, rehabilitation, and modification of real and personal property; tracking and data relay satellite services as authorized by law; purchase, hire, maintenance and operation of other than administrative aircraft; [$4,364,200,000: *Provided*, That notwithstanding any provision of this or any other An. not to exceed $100,000,000 may be transferred to the National Aeronautics and Space Administration in fiscal year 1989 from any funds appropriated to the Department of Defense and such funds may only be transferred to the "Space flight, control and data communications" appropriation for space shuttle operations: *Provided further*, That the transfer limitation in the immediately preceding proviso shall not apply to funds transferred for advanced launch systems or under existing reimbursement arrangements: *h-vided further*, Thar the funds appropriated under this heading are, together with funds permitted to be transferred hereunder] *$5,139,600,000*, to remain available until September 30, [1990] *1991*, *of which $174,435,000 shall be used only for the purpose of reducing outstanding debt to the Federal Financing Bank. (Department of How-ing and Urban Development-Independent Agencies Appropriations Act, 1989; additional authorizing legislation to be proposed.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

REIMBURSABLE SUMMARY
(In thousands of dollars)

	Budget Plan		
	FY 1988	FY 1989	FY 1990
Shuttle production and capability development	135,745	76,400	73,540
Space transportation operations	--	12,400	--
Expendable launch vehicles	162,779	106,300	64,990
Tracking and data acquisition	33.621	38.800	50.400
Total	332.145	233.960	188,930

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1990 ESTIMATES

DISTRUBTION OF SPACE FLIGHT CONTROL AND DATA COMMUNICATIONS BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Spate Cenltr	Goddard Space Flt Center	Jet Propulsion Lab	Ames Rtsearch Ctnttr	Langley Rtsearch Center	Lewis Research Center	NASA HQ
Space Trassportation Sys	1988	2,926,300	907,700	719,700	1,210,000	19,100	27,600	1,700	4,900	100	3,700	31,800
	1989	3,518,900	1,013,900	801,400	1,529,800	20,000	55,000	1,800	6,000	4,000	29,903	57,100
	1990	4,037,500	1,119,600	870,800	1,739,000	18,400	98,000	1,800	6,500	8,000	55,300	120,100
Shuttle Production	1988	1,092,700	328,400	144,400	581,800	17,100	400	1,700	---	---	3,700	10,200
	1989	1,128,200	358,500	164,600	561,100	17,900	---	1,800	---	---	3,400	20,900
	1990	1,305,300	388,100	128,800	706,000	16,000	---	1,800	---	---	3,500	61,100
Space Transporation Ops	1988	1,833,600	579,300	570,300	628,200	2,000	27,200	---	4,900	100	---	21,600
	1989	2,390,700	655,400	636,800	968,700	2,100	55,000	---	6,000	4,000	26,500	36,200
	1990	2,732,200	731,500	742,000	1,033,000	2,400	98,000	---	6,500	8,000	51,800	59,000
Tracking And Data Acqui	1988	879,400	50	---	51,200	---	436,735	129,815	10,500	---	---	251,100
	1989	945,300	---	---	46,600	---	504,600	125,000	11,200	---	---	257,900
	1990	1,102,100	---	---	49,800	---	621,000	156,600	14,000	---	---	260,700
TOTAL BUDGET PLAN	1988	3,805,700	907,750	719,700	1,261,200	19,100	464,335	131,515	15,400	100	3,700	282,900
	1989	4,464,200	1,013,900	801,400	1,576,400	20,000	559,600	126,800	17,200	4,000	29,900	315,000
	1990	5,139,600	1,119,600	870,800	1,788,800	18,400	719,000	158,400	20,500	8,000	55,300	380,800

SPACE
TRANSPORTATION
SYSTEMS

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT

SPACE TRANSPORTATION SYSTEM PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Shuttle production and operational capability............................	1.092.700	1.400.500	1.128.200	1.305.300	SF 1-1
Space transportation operations..........	1.833.600	2.405.400	2.390.700	2.732.200	SF 2-1
Total................................	2,926,300	3.805.900	3.518.900	4,037,500	

Distribution of Proaram Amounts BY Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center.....................	907.700	980.300	1.013.900	1.119.600
Kennedy Space Center.....................	719.700	816.300	801.400	870.800
Marshall Space Flight Center.............	1.210.000	1.412.500	1.529.800	1.739.000
Stennis Space Center.....................	19.100	20.200	20.000	18.400
Goddard Space Flight Center..............	27.600	50.800	55.000	98.000
Jet Propulsion Laboratory................	1.700	1.800	1.800	1.800
Langley Research Center..................	100	23.700	4.000	8.000
Lewis Research Center....................	3.700	125.700	29.900	55.300
Ames Research Center.....................	4.900	6.300	6.000	6.500
Headquarters.............................	31.800	368.300	57.100	120.100
Total...............................	2.926.300	3.805.900	3.518.900	4.037.500

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1990 ESTIMATES

OFFICE OF SPACE FLIGHT **SPACE TRANSPORTATION SYSTEM PROGRAM**

PROGRAM OBJECTIVES

Now that the Space Shuttle has safely returned to flight, the primary program objective of the current activity in the Space Transportation System is to conduct all future flights in a safe and reliable manner and to ensure the establishment of necessary capabilities to meet the manifested flight rate. Total flight requirements will be satisfied with a mixed fleet employing the Space Shuttle and expendable launch vehicle services. The Space Shuttle is the key element of a versatile Space Transportation System (STS) that is available to a wide variety of national users and certain international users. The Space Shuttle is the first reusable space vehicle and is configured to carry many different types of space apparatus, spacecraft scientific experiments, and national security payloads. In addition to transporting materials, equipment and spacecraft to orbit, the Shuttle offers unique capabilities that cannot be achieved with Expendable Launch Vehicles (ELV): retrieving payloads from orbit for reuse; servicing and repairing satellites in space; transporting humans to and returning them safely from space; operating and returning space laboratories; and performing rescue missions.

Shuttle Production and Operational Capability provides for the national fleet of Shuttle orbiters including the replacement orbiter which was fully funded in FY 1987. This budget element also provides for equipment to outfit launch site and flight operations facilities, production tooling, development of an Advanced Solid Rocket Motor (ASRM), and related support activities necessary to provide the capability to safely increase and sustain a Shuttle flight rate up to 14 per year. Shuttle production also provides for the establishment of a logistics system, including an inventory of spare parts and assemblies, to support the operations flights at the 14 per year rate.

This line item contains the following major subdivisions: Orbiter Operational Capability, Propulsion, and Launch and Mission Support. Orbiter Operational Capability includes orbiter design modifications and system improvements, mission kits, procurement of a spares inventory for the operational orbiter fleet, necessary safety modifications identified by the NASA investigation and the Rogers Commission during the post-Challenger accident review process, and continuation of work started in FY 1988 on an Extended Duration Orbiter capability (EDO). Included in the spares inventory is the manufacture of key structural assemblies that also serve to maintain the capability to produce future orbiter vehicles. Propulsion Systems provides for Space Shuttle Main Engines (SSME), External Tank (ET), Solid Rocket Booster (SRB) design improvements, safety modifications, capability investments, rate tooling and development of an Advanced Solid Rocket Motor (ASRM). Launch and Mission Support provides for Johnson Space Center (JSC) mission operations capability development, establishment of an inventory of crew equipment, system-wide capability improvement and equipment provisioning and ground support equipment for the launch and landing facilities at the Kennedy Space Center (KSC).

Space Transportation Operations provides the standard operational support services for the Space Shuttle and Expendable Launch Vehicle services for NASA payload requirements. Within Shuttle Operations, flight hardware is produced, refurbished and repaired; and manpower, propellants, and other materials are furnished to conduct and support both flight and ground operations. Operations funding also provides for replacement of spares inventory for both flight and ground support hardware as it is consumed or damaged as a result of flight related activities. The launch schedule calls for five flights in FY 1989, nine flights in FY 1990, and nine flights in FY 1991. The Shuttle Operations program provides for the launch of NASA missions, as well as missions for DOD, other U. S. Government Agencies and certain commercial and international users on a reimbursable basis. A limited number of foreign and commercial launches are planned based on policy decisions prior to introduction of the mixed fleet policy.

The Expendable Launch Vehicle plan provides launch services for unmanned civil U. S. government space missions not requiring the Space Shuttle's unique capabilities. Initially, expendable launch vehicle services will be procured for selected high priority missions previously manifested on the Space Shuttle. Consistent with the Competition in Contracting Act, expendable launch vehicle services will be acquired from the U. S. private sector when possible.

STATUS

The Shuttle Production and Operational Capability budget provides current funding in three areas: Orbiter Operations Capability, Propulsion, and Launch and Mission Support. The primary thrust of the current effort in orbiter operations capabilities is to complete the development and continue implementation of improvements to key orbiter subsystems such as the auxiliary power unit (APU) and inertial measuring unit (IMU) and safety modifications like the crew escape system and gaseous oxygen flow control valve. In addition, the logistics program continues to procure hardware to establish a spares inventory and equipment for a centralized depot repair capability to fully support the flight program. Activities to provide a new set of structural spares will be initiated in FY 1989. Work continues on the Remote Manipulator System to upgrade a test article to flight status, Work on an Extended Duration Orbiter (EDO), which will extend the orbiter on-orbit stay time beyond the current 10 day capability will be continued. Private sector financing will be explored for selected elements of this program.

The Orbiter Replacement was fully funded in FY 1987. A contract was signed with Rockwell International on August 1, 1987, to produce a replacement orbiter for Challenger using existing structural spares. This replacement orbiter, needed to restore the Shuttle fleet to a full operational level, will be delivered to KSC in April 1991.

Development and life certification of the Space Shuttle Main Engine (SSME) is continuing in support of the flight and ground test program. Design modifications on the high pressure pumps and the hot gas manifold are directed at increasing the SSME operating margins, reducing the SSME operating costs, and determining the hardware life and replacement requirements through a certification extension test program. A major near-term effort is to continue to develop design improvements to the high pressure turbopump blades and bearings to enhance the operating margins and extend their operational life. The long range plan is to replace the high pressure turbopumps with redesigned pumps from an other source. A contractor was selected in 1986 for this effort and full-scale development testing is planned to start in 1991. Redesign of the hot gas manifold is continuing with the design goal of improving flow conditions which will extend engine life by decreasing systems resistance and reducing pump loads. The alternate source turboprops will be introduced into the fleet during the early 1990's and the manifold changes will be implemented during the mid-1990's. The SSME program also includes an advanced technology effort which will provide a technology test bed for detailed SSME environment characterization, and will evaluate potential SSME component and system level improvements, as well as evaluate technical advances arising from the Office of Aeronautics and Space Technology's Space Research and Technology program.

The redesign of the solid rocket motor to resolve deficiencies in the previous design was completed in FY 1988. Flight data will be subjected to detailed analysis in FY 1989 to thoroughly assess the redesign. Production streamlining activities are continuing on the solid rocket booster. In FY 1989 development of an ASRM will be initiated. The ASRM will enhance reliability and safety by eliminating the redesigned SRM constraint of maximizing utilization of existing hardware. Changes in configuration, design details, and materials may be employed to meet more stringent design requirements and enhance safety margins. Production processes will be examined to use the latest applicable technology and automation to enhance reliability and producibility. Significant performance increases are also expected with the ASRM.

At KSC, modifications to major facilities and launch site equipment are continuing to provide for more efficient and reliable launch processing. For example, the Launch Complex 39 permanent weather protection modifications on Pad A will be completed in FY 1989. Additionally, the third mobile launch platform is scheduled to be activated in FY 1989. Other efforts underway include procurement of the Digital Operational Intercom System (OIS-D), extension of the Launch Equipment Test Facility (LETF) to support testing of the facility modifications, incorporation of fiber optics to improve KSC on-site communications between facilities and upgrade of the Orbiter Modification and Refurbishment Facility (OMRF) into an Orbiter Processing Facility (OPF) configuration.

At JSC, modifications to on-going activities have been approved to satisfy post-Challenger accident program requirements. Weather prediction and reporting capabilities are being expanded and the capabilities of contingency landing sites are being enhanced. Readiness of those landing sites associated with polar orbit missions has been deferred consistent with the deferral of the Vandenberg launch site activation. In addition, fidelity and reliability improvements to the training simulators are being given high priority with host computer replacement activity near completion and simulator subsystem replacement continuing.

The Shuttle Operations budget provides funding in three principal areas: Flight Operations, Flight Hardware, and Launch and Landing Operations. Flight Operations includes training, mission control, flight operations planning, payload and systems analytical integration, mission analysis, flight software, postflight anomaly resolution, orbiter sustaining engineering and launch support services.

Flight Hardware includes the replenishment of spares inventory, and repair and refurbishment of orbiter and SSME flight hardware, procurement of external tanks and the interface hardware with the orbiter, refurbishment and manufacturing of solid rocket motors and booster hardware, as well as engineering and logistics support €or external tank/solid rocket booster/main engine hardware elements; and maintenance and operation of flight crew equipment. The funding for the external tank and solid rocket motors and boosters includes long lead procurements of raw materials, subassemblies, and subsystems required to sustain production as the flight rate increases.

The Launch and Landing Operations budget provides funding for processing the elements of shuttle flight hardware as they flow through the ground processing stations at KSC. The Shuttle Processing Contractor (SPC), in conjunction with the Base Operations Contractor (BOC), provides all Shuttle vehicle testing, checkout, servicing, modification and launch processing functions. The Payload Ground Operations Contractor (PGOC) provides processing for all STS payloads from their arrival at KSC through Shuttle integration.

The Expendable Launch Vehicles portion of the mixed fleet plan has been developed as a result of an assessment of NASA's Space Transportation requirements after the Challenger accident. This assessment concluded that several U. S. Civil Government spacecraft should be launched on ELV's in order to provide increased access to space, to assure continuity of space operations, and to enhance mission flexibility. The plan is being implemented in phases. First, NASA plans to procure launch services through directed procurement for missions which require launching by 1991. The missions, under this first phase, are selected high priority missions previously manifested on the Space Shuttle. After the initial phase, the plan is to procure launch services from the private sector on a competitive basis to the maximum extent feasible for identified future requirements.

PRODUCTION
AND OPERATIONAL
CAPABILITY

BASIS OF FY 1990 FUNDING REQUIREMENTS

SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
		(Thousands of Dollars)			
Orbiter operational capability...........	321,300	320,000	281,800	237,000	SF 1-3
Propulsion systems......................	604,000	711,800	582,200	727,300	SF 1-6
Launch and mission support...............	167,400	343,700	264,200	341,000	SF 1-9
Changes and systems upgrading............	--	25.000	--	--	SF 1-12
Total................................	1.092.700	1,400,500	1.128.200	1.305.300	

Distribution of Program Amounts bv Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center....................	328,400	348,300	358,500	388,100
Kennedy Space Center....................	149,400	186,000	164,600	128,800
Marshall Space Flight Center.............	581,800	538,300	561,100	706,000
Stennis Space Center....................	17,100	18,000	17,900	16,000
Goddard Space Flight Center..............	400	--	--	--
Jet Propulsion Laboratory................	1,700	1,800	1,800	1,800
Lewis Research Center...................	3,700	5,700	3,400	3,500
Headquarters............................	10,200	302,400	20.900	61.100
Total....................	1.092.700	1.400.500	1.128.200	1,305,300

OBJECTIVES AND STATUS

The objectives of this program are to provide for the hardware and modifications needed to support the Space Transportation System flight manifest, the completion of the national fleet of Shuttle orbiters, including building a replacement orbiter for the Challenger; the development and production of an Advanced Solid Rocket Motor (ASRM) and other propulsion systems; development of launch site capabilities; and an Extended Duration Orbiter (EDO) capability.

With the loss of Challenger in January 1986, the orbiter fleet was reduced to three vehicles pending delivery of a replacement orbiter. The current orbiter fleet includes Columbia, the orbiter developed and flown on four test and evaluation flights, and two orbiters of a lighter-weight configuration, Discovery and Atlantis. The budget provides funding for necessary improvements, hardware fixes and mission kits for the orbiter fleet to satisfy flight requirements. In addition, the Kennedy Space Center is managing the completion of the orbiter logistics capability and is continuing the procurement of spares needed to support the flight rate buildup. The EDO development is also included to increase on-orbit stay time in order to improve the Shuttle capability to support payload requirements. Current planning is to explore potential sources of private financing for development of selected elements of this program.

Propulsion systems provide for the production of the Space Shuttle Main Engines (SSME), the development of the capability to support operational requirements established for the SSME, SRB, and ET, and the development of an ASRM. The SSME program includes: production of main engines necessary for the orbiter fleet and a spares inventory, ground testing in support of engine development, anomaly resolution and product improvement, and advanced development efforts to improve operating margins.

SRB production and capability development activities include: the reclamation of production verification and 51-L configuration solid propellant motors; investigation of returned flight hardware; procurement of tooling and equipment to support flight rate; and selected studies to continue investigative, analytical, and problem-solving activities.

In FY 1989, a contractor will be selected to develop an Advanced Solid Rocket Motor (ASRM) for delivery in 1994. The program will include the design, development, test, and evaluation of the ASRM. NASA is examining options for private financing of the production facility for this project.

Launch and Mission Support provides for the required investment in Launch Operations and Flight Operations capability to meet STS program objectives, which include supporting a safe flight rate. At KSC, reactivation of launch pad A will complete a second line of facilities allowing simultaneous processing and checkout of orbiters and associated flight hardware from landing through launch. Additional facility and support equipment are being procured to sustain the flight rate capability. At JSC, mission support provides collateral hardware, principally the extra-vehicular maneuvering units (EMU), while mission operations capability provides for improvements in the flight support systems. The flight support systems funded by this budget include training and carrier aircraft, additional landing aids and runway end barriers at the primary and contingency landing sites, and replacement/upgrade of equipment in the mission support complex including the Shuttle Mission Simulator and the Mission Control Center.

BASIS OF FY 1990 FUNDING REOUIREMENT

ORBITER OPERATIONAL CAPABILITY

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Orbiter.................................	194,800	181,000	155,800	157,500
Extended duration orbiter................	--	10,000	20,000	25,000
Systems integration....................	30,800	17,700	30,500	9,000
Orbiter spares..........................	88,400	54,000	55,200	30,300
Structural spares......................	7,300	57,300	20,300	15,200
Total.................................	321,300	320,000	281,800	237,000

OBJECTIVES AND STATUS

Orbiter production activities include the development and implementation of hardware, software, and procedures modifications identified by the Rogers Commission and the post-Challenger accident review process to improve safety and appellation margins. Also, work continues on improvements to achieve greater operational capabilities, reduce operational costs, and meet system requirements. These improvements include upgrading the general purpose computers (GPC), inertial measurement units (IMU), and auxiliary power units (APU). The brake and the nose wheel steering systems are undergoing modifications to improve landing performance. In addition to these system changes, there are numerous mission and modification kits required for specific flights and payloads. Also included will be the work necessary to continue development of a 16 day extended duration orbiter (EDO) capability and initial efforts for further extension up to 28 days. EDO will be developed using private financing if key safety and integration issues can be successfully resolved.

The procurement and fabrication of the orbiter spares inventory is ongoing. A concerted effort has been made to better define the spares requirements and production capability at various vendors. A logistics depot has been established at KSC for repair and maintenance of orbiter flight and ground support hardware. The on-site depot will reduce repair costs and shorten turnaround time by reducing requirements to return failed hardware to the original manufacturer. The depot is currently repairing and maintaining minor line replaceable units (LRU) and shop replaceable units (SRU) and is scheduled to transition to major repair activity and become fully operational by FY 1993.

The structural spares program initiated in FY 1983 provided the foundation for the production of the replacement orbiter (OV-105). It is necessary to initiate the fabrication of a new set of structural assemblies to replace those used in the production of OV-105. This effort, to begin in FY 1989, will provide a minimum capability to produce another vehicle in addition to providing additional hardware for inventory. Structural assemblies include the wings, aft thrust structure, engine compartment, crew module (including the nose and cockpit), mid and aft fuselage sections, payload bay doors, vertical tail, and the orbital maneuvering system pods.

CHANGES FROM FY 1989 BUDGET

FY 1989 funding for orbiter operational capability activities decreased $38.2 million. This is due to a slower start of structural spares, the delay and deletion of orbiter modifications, and the addition of $10 million to initiate activities toward a 28 day EDO capability consistent with Congressional direction.

BASIS OF FY 1990 ESTIMATE

Orbiter funds provide for the completion of previously approved systems improvement programs, necessary safety modifications identified as a result of the Challenger accident review process, and the engineering analysis and integration capabilities to support the flight rate. Orbiter funding also provides for similar activities on orbiter support hardware such as the remote manipulator system. In FY 1990, work on the 16 and 28 day EDO capability will continue with possible participation of private sector financing if safety and integration issues can be resolved.

The development, qualification and production of flight units for an improved auxiliary power unit (APU) and the upgrade of the general purpose computers (GPC) will be completed. The improved APU will have longer life and higher reliability and will require substantially less ground servicing. This configuration will preclude recurrence of problems which have occurred on prior flights such as the formation of wax due to the mixing of lube oil and fuel. The new GPC will add memory and increase operating speed in order to resolve the operational limitations of the current hardware and will result in a more reliable system.

Orbiter funding also covers systems integration of all redevelopment analyses and hardware changes, as well as procuring orbiter support items.

The EDO provides for the development of a cryogenic pallet kit to extend the on-orbit stay time in order to provide significantly greater time for payloads to complete their mission objectives. Cryogenic pallets will accommodate tank sets needed to supply the fuel cells with additional reactants needed to generate electrical power for the added time on-orbit. The program should be completed in FY 1992 with the modification of an existing orbiter. Efforts on the 28 day EDO will start in FY 1989 which may lead to development of the expanded capability in FY 1990. Issues under evaluation include orbiter auto-land requirements, the effect of long-duration space flight on crew capabilities, power availability compared to other power sources, and the feasibility of privately financing some parts of the EDO.

The orbiter logistics capability program in FY 1990 is continuing the lay-in of LRU's, SRU's, and repair parts to support the flight rate buildup. The funding covers the procurement of flight hardware and ground equipment hardware for inventory as well as necessary documentation, scheduling, provisioning and maintenance training. Funding is also included to provide maintenance test equipment and special test equipment to continue outfitting the centralized depot and selected vendor repair sites. In addition, a low-level of effort to preserve the option to manufacture additional structural spares will be continued.

BASIS OF FY 1990 FUNDING REQUIREMENT

PROPULSION SYSTEMS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Main engine.............................	395,900	511,800	400,500	496,600
Solid rocket booster....................	161,200	105,000	123,700	106,700
External tank...........................	36,000	7,000	7,000	2,700
Systems support.........................	--	--	--	--
Advanced solid rocket motor.............	10,900	88,000	51,000	121,300
Total................................	604,000	711,800	582,200	727,300

OBJECTIVES AND STATUS

The Propulsion Systems budget provides for the production of and continued efforts to improve operating margins for the Space Shuttle Main Engines (SSME); the implementation of the capability to support operational requirements and anomaly resolution for the SSME, Solid Rocket Booster (SRB), and External Tank (ET); and the development of the Advanced Solid Rocket Motor (ASRM). The SSME program includes the production of the main engines required for the orbiter fleet, the procurement of spare engines, ground testing operations, development and certification activities to improve operating margins, reliability and durability, and anomaly resolution capability. The SRB program includes the reclamation or replacement of reusable hardware destroyed or made obsolete by the Challenger accident redesign and subsequent ground testing of the SRB redesign, continuation of test data analyses and evaluation, completion of solid rocket motor (SRM) tooling modifications and procurement of transportation equipment to support the projected flight rate. Engineering analysis and modification of booster hardware for certification of a twenty flight use capability will continue in FY 1990. The ASRM will replace the current SRM and may employ changes in configuration, design details, and materials to meet more stringent design requirements and enhance safety margins.

The SSME program has been structured into three major elements under Shuttle Production and Operational Capability: (1) flight engine; (2) development engine; and (3) advanced development. The total SSME experience now exceeds 2,255 tests, totaling approximately 362,000 seconds of test and flight time. This experience includes 319 tests, exceeding 70,818 seconds of operation, at the full power level (FPL).

The flight engine activity includes the production of new engines, retrofit of improved hardware into the fleet, and engineering analysis of ground test and flight engine performance.

The development engine activity provides for the ground test program including hardware, propellants, and test support, and for the development, certification, and flight certification extension of improved hardware including a redesigned hot gas manifold and near-term high pressure turbopump improvements such as improved blades and bearings.

Following of the Challenger accident, the SSME program has delayed all activities associated with the operational use of FPL (109 percent). Single engine testing at these levels has continued to demonstrate margin and safety for the life certification extension test program. In addition, testing is required to demonstrate capability to support extreme abort modes which require operation at FPL. The Stennis Space Center (SSC) main propulsion test stand capability is being maintained on a minimum basis for the eventual FPL test of three clustered engines. This test will provide for a verification of the main propulsion system operations at full power level using the main propulsion system test hardware mounted in the aft end of the simulated orbiter.

The advanced development activity includes the alternate turbopump program and the technology test bed. An alternate source for high pressure turbopumps was selected in August, 1986. These alternate pumps will be designed for greater reliability and safety margins, and longer life leading to lower operational costs. The technology test bed will provide an independent means to evaluate the technical advances arising from the development program, the alternate pump effort, and the Office of Aeronautics and Space Technology research and technology program.

The redesign of the SRB to resolve deficiencies in the previous design was completed in FY 1988. Assessment of flight data, including analysis and evaluation, will be continuing in FY 1989. There will be a continuing activity to improve tooling and procedures to enhance process control and product quality. Reclamation of reusable SRM hardware produced prior to the Challenger accident will be accomplished through static firing and refurbishment. Refurbishment of the case hardware will include modification to the redesigned configuration.

The Advanced Solid Rocket Motor (ASRM) project is intended to enhance the flight safety, reliability and performance of the Space Shuttle fleet. The ASRM will not be subject to the constraint of maximum use of existing hardware that limited changes on the recent SRM design activities. The ASRM may employ changes in configuration, design details, and materials to meet more stringent design requirements and enhance safety margins. Production processes will be examined to use the latest applicable technology and process automation to enhance reproducibility and reliability. The ASRM project also includes development and certification of asbestos free insulation necessary to insure a viable source for future manufacturing of solid rocket motors. A primary objective of the ASRM is to achieve increased payload capability with the requirement that there be no compromise to flight safety and reliability, and that the impact to other Shuttle elements be held to an absolute minimum.

During the ASRM definition studies, completed in 1988, contractors did preliminary designs of a segmented motor. Also, they provided design data on a modern, automated production facility to maximize material and process controls for enhanced reliability. Development is scheduled to begin in the second quarter of FY 1989 with the selection of a Phase C/D contractor. The ASRM is planned to be ready for first flight in FY 1994.

CHANGES FROM FY 1989 BUDGET

FY 1989 funding requirements in Propulsion decreased $129.6 million. A $111.3 million decrease in the main engine program to accommodate the Congressional general reduction will be accomplished by delaying the planned procurement of an attrition engine, and by reducing the technology test bed and development activities. In addition, the external heat exchanger development will be funded under the replacement orbiter program consistent with its first use on that vehicle. The ASRM has been reduced $37 million. This is consistent with Congressional direction to transfer $27.5 million to the Construction of Facilities appropriation and an evaluation of funding requirements associated with the deferral of work due to delay in initial procurement actions. An increase of $18.7 million in the SRB is due to increased process improvements and recertification efforts.

BASIS OF FY 1990 ESTIMATE

Achievement of the planned Space Shuttle flight rate of up to 14 launches per year requires continued investment in improved propulsion systems and capabilities. The SSME program will continue the production of flight hardware and the development activities including necessary improvements to the current configuration and the alternate turbopump programs. The SRB funding will primarily focus upon continued evaluation and analysis of flight data to thoroughly assess the redesign. In addition, efforts will continue on improvements to the solid rocket motor manufacturing process and the reclamation or replacement of pre-Challenger reusable hardware and modification of booster hardware necessary to obtain 20 flight use capability. The External Tank program supports the production of tanks with acquisition of off-the-shelf test and manufacturing support equipment.

The Request for Proposal (RFP) for the development phase of the ASRM was issued in August 1988. One contractor will be selected for development with contract start anticipated during the spring of FY 1989. The development program is anticipated to extend for five years with the first flight in late 1994. The scope of the development will include modification or acquisition of facilities, the development and test of the new design, and production of verification units. The ASRM development is comparable in scope and complexity to that of the SRM, while the technological base is more mature than that at the start of the SRM project.

BASIS OF FY 1990 FUNDING REQUIREMENT

LAUNCH AND MISSION SUPPORT

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Launch site equipment...................	60,800	142,000	109,400	98,500
Mission support capability...............	31,400	93,500	42,100	75,600
Mission operations capability............	75.200	108,200	112.700	166.900
Total................................	167.400	343,700	264.200	341.000

OBJECTIVES AND STATUS

This activity supports the development of launch and mission support capabilities, principally at the Johnson Space Center (JSC) and Kennedy Space Center (KSC). The launch site equipment budget provides the capability to support processing and checkout of up to three orbiters in flow and to sustain the operational launches at KSC. With the reactivation of Pad A in FY 1990, two complete lines of facilities will be in place to support parallel processing. A third mobile launch platform will be reactivated in FY 1989 and the orbiter modification and refurbishment facility (OMRF) will be fully outfitted into a third orbiter processing facility utilizing support equipment from the Vandenburg launch site. Launch site equipment also provides for the replacement and upgrade of existing ground support systems due to obsolescence or increasing flight requirements. In addition, funds are provided to improve capabilities including the automated data management system for launch processing documentation recommended by the Rogers Commission.

Funding has been included for upgrading landing aids for end of mission and contingency/abort landing sites. Capability improvements have been added for weather prediction and information handling to improve system monitoring, notably for anomaly tracking. Funding for a preflight adaptor trainer has also been added to help prepare the crews for a weightless environment. Consistent with the recommendations of the Rogers Commission, improvements are being made in simulation training including new host computers, interface hardware, and simulator subsystem replacement. Critical improvements in simulation fidelity will be accommodated with the expanded capacity of the new hardware. Reliability required for the longer integrated simulations, and associated maintenance cost will also be substantially improved with these replacements. Other activities include implementing required modification and upgrades on the T-38 proficiency aircraft and procuring a fourth Shuttle Training Aircraft and a second Shuttle Carrier Aircraft. Procurement of additional extravehicular mobility units and associated improvements are also included.

CHANGES FROM FY 1989 BUDGET

The Launch and Mission Support total has decreased $79.5 million. The aunch site equipment decrease of $32.6 million reflects a deferral in the planned upgrade of the Central Data System element of the Launch Processing System and a savings realized by utilizing Vandenberg launch site equipment in the upgrade of the OMRF to an OPF.

Mission support capability decreased by $51.4 million as program reserves were deleted to comply with the FY 1989 Appropriations general reduction.

Mission operations capability increased by $4.5 million to continue the required equipment improvements in the training, landing, and mission control facilities and development of the Program Compliance Assurance and Status System (PCASS). Other increases include the addition of a the Flight Analysis and Design System (FADS) which will automate and standardize the flight design process to accommodate for the increasing flight rate and a "swing" flight control room (FCR) to allow current secure facilities to support both secure and non-secure missions. These increases were partially offset by a rephasing of the fourth Shuttle training aircraft delivery into FY 1991 consistent with the revised mission model.

BASIS OF FY 1990 ESTIMATE

In FY 1990, Launch Site Equipment includes activities to improve the capability to support the flight rate requirements at KSC. These include development of the automated data management system to improve the paperwork flow and traceability of launch processing, continuation of the replacement of Apollo era internal communications system with a digital system using fiber optics cabling, upgrade of the orbiter modification and refurbishment facility to an orbiter processing.facility, replacement equipment €or the launch processing system, extension of the launch equipment test facility (LETF), reactivation of Pad A and enhancement of equipment at contingency landing sites. Continued identification, replacement and upgrading of obsolete ground processing and support equipment will be accomplished.

Mission support capability funds are required to establish an inventory of crew equipment, principally additional extravehicular mobility units (EMU), to support the flight rate. STS operations effectiveness work and other support functions continue to support STS program-wide requirements including flight safety, mission success, and rate capability.

Mission operations capability funding in FY 1990 provides for completing replacement of the host computers and selected critical items for the Shuttle training simulators in addition to replacement of ADP and other hardware in the Mission Control Center. Continuing projects include developing and implementing the Flight Analysis and Design System (FADS), Program Compliance Assurance Status System (PCASS), and the "swing" Flight Control Room (FCR), as well as improvements to weather prediction, information handling, mission control systems, and contingency landing sites. Also included is the continued development of a preflight adaptor trainer to prepare the crew for a gravity-free environment and the ongoing aircraft modifications for the fourth Shuttle Training Aircraft and a second Shuttle Carrier Aircraft.

BASIS OF FY 1990 FUNDING REQUIREMENT

CHANGES AND SYSTEMS UPGRADING

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Changes and systems upgrading............	--	**25,000**	--	--

OBJECTIVES AND STATUS

Management, technical flight experience, and cost reviews of the Shuttle program have stressed the need for providing an allowance for changes and modifications which inevitably are required in a large, complex, and technically demanding space system. Current funding pressures preclude maintaining **a** separate changes and systems upgrading budget. Continuing minor changes and modifications will be accommodated as necessary within the available funding for each Shuttle line item and major changes will be proposed separately.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The $25 million reduction was made in order to comply with the Congressionally directed general reduction.

OPERATIONS

BASIS OF FY 1990 FUNDING REQUIREMENT

SPACE TRANSPORTATION OPERATIONS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
	(Thousands of Dollars)				
Flight operations......................	597,100	660,100	685,700	772,600	SF 2-3
Flight hardware........................	756,300	1,035,200	1,112,700	1,236,500	SF 2-6
Launch and landing operations............	452,200	514.600	506.800	553.600	SF 2-8
Shuttle operations....................	1,805,600	2,209,900	2,305,200	2,562,700	
Expendable launch vehicles and services..........................	28.000	195,500	85.500	169.500	SF 2-10
Total................................	1.833.600	2,405,400	2.390.700	2.732.200	

Distribution of Program Amounts by Installation

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
Johnson Space Center....................	579,300	632,000	655,400	731,500
Kennedy Space Center....................	570,300	630,300	636,800,	742,000
Marshall Space Flight Center.............	628,200	874,200	968,700	1,033,000
Stennis Space Center....................	2,000	2,200	2,100	2,400
Goddard Space Flight Center..............	27,200	50,800	55,000	98,000
Langley Research Center..................	100	23,700	4,000	8,000
Lewis Research Center...................	--	120,000	26,500	51,800
Ames Research Center....................	4,900	6,300	6,000	6,500
Headquarters...........................	21.600	65.900	36.200	59.000
Total................................	1.833.600	2.405.400	2.390.700	2.732.200

OBJECTIVES AND STATUS

Space Transportation Operations provides launch services to NASA payloads using a mixed fleet approach of both the Shuttle and Expendable Launch Vehicles. Launch services are also provided, on a reimbursable basis, to the Department of Defense, other civil agencies, and certain commercial and international users. The Shuttle program launch schedule is based on five flights in FY 1989, nine in FY 1990 and nine in FY 1991. The ELV planning reflects use of a mix of launch systems based on individual payload requirements.

The Space Shuttle has demonstrated a broad range of capabilities including deployment of spacecraft and their upper stages, satellite repairs, satellite retrieval, operations using the remote manipulator, integral scientific experimentation using Shuttle and Spacelab systems, and extravehicular activity operations. These capabilities provide a unique opportunity to enhance the scientific return of many payloads and the Shuttle will remain the mainstay of **NASA's** launch capability. The major program elements of Shuttle Operations are Flight Operations, Flight Hardware and Launch and Landing Operations. These elements provide for the standard service operation of the Shuttle including preflight preparation activities, procurement and refurbishment of flight hardware and maintenance and operation of equipment and facilities necessary to support all phases of the Shuttle flight process.

The Flight Operations activity is divided into three major elements: mission support, integration, and support. Mission support includes training, flight operations activities and a wide variety of planning activities ranging from operational concepts and techniques to detailed systems operational procedures and checklists. Integration includes launch support services and sustaining engineering for orbiter systems, cargo analytical integration, and systems integration. The support element includes systems support activity at JSC such as aircraft operations, engineering support, and support to the National Space Transportation System (NSTS) program office. Shuttle system support at Headquarters and the Marshall Space Flight Center and Stennis Space Center is also included.

The Flight Hardware program element provides for: the procurement of external tanks (ET) and solid rocket booster (SRB) elements including motors, booster hardware, and solid propellants; replenishment of spare parts inventory and repair of the reusable Space Shuttle Main Engine (SSME), orbiter and crew equipment; ET disconnects, logistics support for the orbiter ET, SRB, and SSME flight hardware elements; and maintenance and operations of flight crew equipment. Included in the funding request for tanks and boosters are the long lead time raw materials, subassemblies, subsystems and additional ground testing of the redesigned Solid Rocket Motor (SRM) necessary to sustain and verify the production of elements in a manner consistent with the flight rate requirements.

Launch and Landing Operations provides for the prelaunch preparation, liquid propellants, launch, and landing operations of the Shuttle and its cargo.

In addition to being the primary launch vehicle for **NASA** missions, the Shuttle provides launch support to approved payloads on a reimbursable basis. Because of the Challenger accident, however, there are currently *$12.4* million in FY 1989 and no planned reimbursable funds for Shuttle Operations in FY 1990.

The Expendable Launch Vehicles/Mixed Fleet plan was initiated after the Challenger accident as a result of an assessment of **NASA's** space transportation requirements. This assessment showed that several U. S. Civil Government spacecraft should be launched on ELV's in order to provide increased access to space, to assure continuity of space operations, and to enhance mission flexibility. The missions currently planned for launch on ELV's are spacecraft requiring West Coast launches and selected East Coast launches which do not require the Shuttle's unique *capabilities and can transition to ELV's without significant impact to the spacecraft.

BASIS OF FY 1990 FUNDING REOUIREMENT

FLIGHT OPERATIONS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Mission support........................	197,700	215,400	230,500	247,500
Integration............................	233,800	264,100	268,800	300,300
Support................................	165.600	180,600	186.400	224.800
Total..................................	597,100	660,100	685.700	772.600

OBJECTIVES AND STATUS

Flight operations is divided into three major areas of activity: mission support, integration, and support. Mission support includes a wide variety of preflight planning, crew training, and operations control activities. The planning activities range from the development of operational concepts and techniques to detailed systems operational procedures and checklists. Tasks required for each flight include flight planning, preparation of systems and software handbooks; establishment of flight rules, detailed crew activity plans and procedures; development and implementation of the mission control center (MCC) and network system requirements for each flight; and operations input to the planning for the selection and operation of Shuttle payloads. Specific flight planning activity encompasses the flight design, flight analysis, and software activities. Flight design products include conceptual flight profiles and operational flight profiles which are issued for each flight as well as support to the crew training simulations and flight techniques. In addition, the flight-dependent data located in the erasable memory (mission-to-mission changes) is developed in the flight design process for incorporation into the orbiter software, Shuttle mission simulator, and MCC systems. Also included are the maintenance and operation of critical mission support facilities including the mission control center, flight simulators, crew training, and flight software reconfiguration and recertification facilities.

Integration includes orbiter sustaining engineering, payload integration into the Shuttle, system integration of the flight hardware elements, orbiter launch support services to the launch site and flight development and verification software. The orbiter sustaining engineering provides all prime contractor engineering activities necessary to re-qualify each orbiter for flight including FMEA/CIL, design changes and certification reviews. The software activities include the development, formulation, and verification support of the guidance, targeting, and navigation systems software requirements in the orbiter.

Support includes base operations support to Shuttle operations and systems level support at the manned space flight centers. Base operations support provides for operation and maintenance of aircraft for flight training, crew proficiency and the ferry requirements; engineering and supporting activities for the orbiter, crew equipment, and flight operations systems; and support to the NSTS program office.

Currently, the resources for Flight Operations are focused upon providing the flight products necessary to support the manifested flight rate, fixing a backlog of system discrepancies and incorporating a large number of changes to ground systems hardware, software, and procedures including those resulting from the ongoing process of analysis and decision-making in the wake of the Challenger accident. Flight preparation, training of ground and flight crews (including system-wide integrated simulations), and other functions are being carried out. These efforts are critical to the safe operation of the Shuttle and significant emphasis is being placed on ensuring that the flight products and crew training satisfy revised and more stringent operational requirements.

CHANGES FROM FY 1989 BUDGET

The Flight Operations direct budget increased $25.6 million in order to support more extensive system design reviews, flight product verification and safety/reliability oversight. Mission support has increased $15.1 million due to STS operations contract increases, additional support for operations of the flight software verification facilities and also to reflect additional fidelity and verification in the flight design and software reconfiguration activities over previously estimated levels. Integration has increased $4.7 million due to a consolidation of flight software activities and increased engineering oversight by NSTS and the program office over the Shuttle projects, including the operation of a comprehensive system-wide Shuttle data base which will store and track performance and failure history for each major subsystem within every Shuttle project (e.g., SRM, ET, Orbiter). Support requirements have increased by $5.8 million primarily to accommodate increased requirements at JSC and SSC for information processing and equipment.

BASIS OF FY 1990 ESTIMATE

The Flight Operations portion of the Shuttle Operations budget continues to support that activity predominately associated with the effort at JSC to plan for and conduct STS missions from launch to landing. The functions in Mission Support and Support are essentially the same as in the past: to maintain and operate all the ground facilities necessary for flight preparation and execution, and to train the flight and ground controller crews; to maintain and operate aircraft for proficiency training and orbiter ferry requirements and to perform the mission planning necessary for each mission. These activities will support the increase in flights to 9 in FY 1990. In addition, independent cargo hazard analysis will be expanded and funds are required to support a reduction in planned DOD secure flight support.

Flight Operations also includes the sustaining engineering required to integrate all flight and ground elements and to assure systems safety and integrity; the analytical integration of the payloads into the orbiter and the planning to assure compatibility and verification of interfaces; and support of crew operations and training programs. Orbiter engineering manpower continues the required support of procedure and hardware modifications resulting from the FMEA/CIL reviews in addition to the sustaining engineering activities that ensure maintainability, reliability, and anomaly resolution during operations. Integration efforts will support the increase in flight activity in FY 1990 as development efforts funded under Orbiter Operational Capability are completed.

BASIS OF FY 1990 FUNDING REQUIREMENT

FLIGHT HARDWARE

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Orbiter..................................	269,200	339,400	301,300	351,800
Orbiter spares..........................	(105,700)	(120,100)	(116,400)	(167,600)
Solid rocket booster....................	200,500	382,500	516,800	537,000
External tank...........................	286.600	313,300	294.600	347.700
Total................................	756.300	1,035,200	1,112,700	1.236.500

OBJECTIVES AND STATUS

The Flight Hardware program element provides for the procurement of External Tanks (ET), the manufacturing and refurbishment of Solid Rocket Booster (SRB) hardware and motors; and operational support to the Orbiter elements including the orbiter, external tank disconnects, main engines (SSME) and crew equipment. Included in the funding request for tanks and boosters are the long lead raw materials, subassemblies, and subsystems necessary to sustain the production of these elements in a manner consistent with the increasing flight rate. Production phasing of these elements is based on the current flight traffic model and is structured to maintain a smooth and efficient buildup of the production capability. Included also are static test firings of two production type solid rocket motors a year in order to continue verification and analysis of the SRM redesign. In the ET, production continues at a minimum level of activity necessary to retain manufacturing capability. The Orbiter line element includes replenishment of the spare parts inventory of line and shop replaceable units, the manpower for supporting the logistics operation, and the repair capability for flight hardware. Also included is the procurement of expendable hardware consumed in flight operations, field support, and maintenance of crew-related equipment as well as SSME flight support and engine overhauls. Some examples of orbiter equipment requiring logistics support are fuel cells, tiles for thermal protection, tape recorders, leading edge support structures, wheels, brakes and pyrotechnics. The crew-related equipment activities include support to preflight training and flight usage of the extravehicular maneuvering unit, emergency portable oxygen systems, radiation instrumentation, survival radios, closed-circuit television cameras, medical support, and food and other galley-related items.

NGE FROM FY 1989 BUDGET

The orbiter project has reduced requirements by $38.1 million by rescheduling engine component refurbishment, utilization of available inventory hardware resulting from lower than planned test levels, and reduced requirements from the lower flight model. SRB requirements have increased $134.3 million as the result of a thorough program reassessment following completion of the return to flight activities. As a result of this review the SRB hardware will be subject to stringent production and reuse controls, dramatically expanded quality control and inspection and augmented engineering and assessment. The external tank has decreased $18.7 million due to the reduced mission model production requirements and rephasing of the fifth production buy.

BASIS OF FY 1990 ESTIMATE

Requirements for Orbiter spare parts consumption, repairs and logistics operations are based on projected flight rates, maintenance schedules, operational usage, repair times, and lead times to procure or repair flight hardware. The budget provides replenishment line and shop replaceable units, as well as the manpower to support the overhaul and repair activity for the orbiter, extravehicular maneuvering unit and other crew equipment. The flight equipment processing contractor (FEPC), which was initiated during FY 1986, is continuing its buildup to full capability to support the projected flight rates. Main Engine hardware provides for refurbishment and delivery of overhauled engines, replenishment or repair of engine component spares and flight support.

Flight hardware requirements activity for the SRB and ET include the procurement of the materials and labor required for refurbishment and manufacturing activities necessary to support flight requirements. The SRB project will increase flight set deliveries from 6 in FY 1989 to 9 in FY 1990. The ET will remain at the minimum delivery schedule of 4 per year through FY 1990. These projects, particularly the ET, have extended manufacturing cycles and long-lead materials procurements. As a result, a significant part of the FY 1990 funding is required to support the increased flight rates planned for subsequent years. Additionally, the first flight support motor static firing test will be conducted to monitor the consistency of production characteristics of the solid rocket motors and to provide a data base for continuing engineering evaluations and design changes.

BASIS OF FY 1990 FUNDING REQUIREMENT

LAUNCH AND LANDING OPERATIONS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Launch operations.......................	409,200	456,600	452,800	492,500
Payload and launch support...............	43.000	58,000	54,000	61.100
Total...................................	452.200	514.600	506.800	553,600

OBJECTIVES AND STATUS

Launch and Landing Operations provides for the manpower and materials to process and prepare the Shuttle flight hardware elements for launch as they flow through the processing facilities at **KSC.** Standard service processing and preparation of payloads as they are integrated into the orbiter are also funded by this category as is procurement of liquid propellants for launch and base support. Support to landing operations at KSC and contingency sites, as required, is also provided.

Operation of the launch and landing facilities and equipment at KSC is the primary function of the Shuttle Processing Contractor (SPC). This includes stacking and mating of the flight hardware elements into a launch vehicle configuration, verification of the launch configuration, and operation of the launch processing system prior to lift-off. Support is also provided by the SPC for booster retrieval operations, configuration control, logistics, transportation, and inventory management.

Support to Shuttle processing is provided by the Base Operations Contractor or (BOC). The BOC is responsible for operations support functions such as processing propellants, life support systems, railroad maintenance, pressure vessel certification, Shuttle landing facility and facility and equipment modifications.

Other launch support services included in this budget are maintenance and repair of the central data subsystem, which supports Shuttle processing as an on-line element of the launch processing system; range support provided by the DOD; Shuttle related data management functions such as work control and test procedures; and purchase of equipment, supplies and services not procured under the Shuttle processing contractor.

The Payload and Ground Operations Contract (PGOC) is the major contract for the payload processing activities. In Shuttle Operations, the PGOC contractor provides the standard service processing of all STS payloads into an integrated cargo prior to loading into the Shuttle. PGOC will also be the primary contractor for Spacelab and Space Station payload processing at KSC, funded under their respective budgets.

CHANGES FROM FY 1989 BUDGET ESTIMATE

Direct funding requirements for Launch and Landing Operations reflect a decrease of $7.8 million. This reduction is the net result of a decrease of $9.6 million due to lower unit cost of propellants and flight rate adjustments, offset by increased requirements of $1.8 million to support manpower at contingency landing sites and for increased thermal protection system repair and replacement activity.

BASIS OF FY 1990 BUDGET

Launch operations funding in FY 1990 provides €or manpower and support services necessary for processing the planned increase to 9 launches from KSC. This includes manpower to assemble the SRB's, mate the boosters and tanks, process the orbiter, mate the orbiter to the integrated SRB's and tank, process and checkout integrated flight elements through launch, retrieve the SRB's for refurbishment, and support landing of the orbiter at both the primary and contingency landing sites. Funding also supports the manpower required for sustaining engineering, launch processing system operation and maintenance, and maintenance/modification of all other Shuttle-related ground support equipment and facilities. Flight safety will continue to be emphasized through testing, engineering and quality control. Additional manpower and support services are required to operate Pad A and MLP 3 which will be activated at the start of the year.

Payload and launch support funding provides propellants for launch operations and base support, and contractor support for the assembly of individual payloads into a total cargo. This element includes providing launch site support managers to payload customers, verifying cargo-to-orbiter interface, and providing operations maintenance and logistic support to cargo support equipment (such as cargo integration test equipment and multi-mission payload support equipment) and to the payload support areas including the Vertical Processing Facility, Operations and Checkout building, and cargo hazardous servicing facilities.

BASIS OF FY 1990 FUNDING REQUIREMENT

EXPENDABLE VEHICLES AND SERVICES

	1988 Actual	1989 Eudget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Small class..............................	--	23,700	14,000	26,300
Medium class............................	28,000	53,300	46,500	86,200
Intermediate class......................	--	75,100	5,000	54,900
Large class..............................	--	43,400	20,000	2,100
Total	28,000	195,500	85,500	169,500

OBJECTIVES AND STATUS

The Expendable Launch Vehicles/Mixed Fleet Program, initiated in 1987, will provide launch services for selected NASA payloads not requiring the Space Shuttle's unique capabilities. Under Phase I of this program, funds being provided in FY 1989 will continue to be utilized for procurement of Delta II vehicles and launch services through the DOD under the QUID PRO QUO for the Roentgen Satellite (ROSAT) and Extreme Ultraviolet Explorer (EWE) missions. In addition, NASA is preparing a Delta vehicle for launch of its Cosmic Background Explorer (COBE) mission in mid-1989 using funds reimbursed by DOD for residual Delta vehicle hardware. Titan III commercial launch service is being procured for launch of the Mars Observer spacecraft in September 1992. NASA is also executing an exchange of residual assets from previous NASA programs for an Atlas/Centaur commercial vehicle from General Dynamics for launch of the Combined Release and Radiation Effects Satellite (CRRES) in support of a June 1990 launch. Several of the planned CRRES experiments which cannot be accommodated on the Atlas/Centaur will be launched on a Scout vehicle.

Phase II ELV launch services will be acquired by NASA competitively, whenever possible, to launch civil government payloads in four performance classes: (a) small class capable of launching payloads up to 1,000 lbs, (b) medium class capable of launching payloads up to 10,000 lbs, (c) intermediate class capable of launching payloads up to 30,000 lbs, and (d) large class capable of launching payloads of 40,000 lbs or more into low Earth orbit. NASA will acquire launch services through the DOD, whenever competitive commercial launch services in a particular class are not available.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The Expendable Launch Vehicle funding is reduced $110 million consistent with Congressional action. Funding for the Titan III for TDRS has been eliminated and the spacecraft will be manifested on the Shuttle. The planetary backup Titan IV has been deleted based upon the inability of the Air Force to support vehicle delivery and launch in the desired timeframe. The planetary launches will receive the highest priority available on the Shuttle.

BASIS OF FY 1990 ESTIMATES

Funds are required in FY 1990 to complete procurement through the DOD under the QUID PRO QUO for the launch of the ROSAT mission on a Delta II in February 1990, and continue procurement of the launch vehicle for the EWE mission planned in FY 1991. In addition, funds are required for mission-unique hardware for the launch of the CRRES mission on a commercial Atlas/Centaur in June 1990.

Initial funding will be required for the procurement of commercial launch services for: (a) a series of projected medium-class missions starting with the currently approved GEOTAIL and WIND missions of the Global Geospace Science Project targeted for launch in FY 1992 and FY 1993 as well as for the Polar and MSAT missions targeted for launch in FY 1993; and (b) a series of Small Explorer Satellite class missions planned to be launched at a rate of two per year starting in FY 1992. These small class missions are described in a recent NASA Announcement of Opportunity of the NASA Office of Space Science and Applications dated May 14, 1988. This funding request takes into consideration the recent NASA/DOD Agreement allocating three of six Scout vehicles currently remaining in the DOD inventory to support two NASA launches in FY 1991 and one in FY 1992.

The acquisition of the Titan III commercial launch services will be continued for the Mars Observer mission scheduled for launch in FY 1992. The initial phase of mission integration services necessary for a Titan IV launch of CRAF and an intermediate class launch of SOHO in 1995 will also be initiated.

TRACKING AND DATA
ACQUISITION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1990 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE OPERATIONS

SPACE AND GROUND NETWORKS. COMMUNICATIONS AND DATA SYSTEMS

SUMMARY OF RESOURCES REQUIREMENTS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate	Page Number
	(Thousands of Dollars)				
Space network..........................	433,400	538,900	483,900	582,300	SF 3-4
Ground networks........................	231,000	248,100	228,100	269,600	SF 3-12
Communications and data systems..........	215.000	248.300	233.300	250,200	SF 3-21
Total............................	879.400	1035.300	945,300	1102.100	
Distribution of Program Amounts by Installation					
Marshall Space Flight Center.............	51,200	49,100	46,600	49,800	
Goddard Space Flight Center..............	436,735	572,900	504,600	621,000	
Jet Propulsion Laboratory................	129,815	140,200	125,000	156,600	
Ames Research Center....................	10,500	11,900	11,200	14,000	
Headquarters............................	251,100	261,200	257,900	260,700	
Johnson Space Center....................	50	---	---	---	
Total................................	879.400	1035,300	945,300	1102,100	

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1990 ESTIMATES

OFFICE OF SPACE OPERATIONS

SPACE AND GROUND NETWORKS, COMMUNICATIONS AND DATA SYSTEMS

PROGRAM OBJECTIVES AND JUSTIFICATION

The purpose of this program is to provide vital tracking, telemetry, command, data acquisition, communications and data processing support to meet the requirements of all NASA flight projects. In addition to NASA flight projects, support is provided on a reimbursable basis for projects of the Department of Defense (DOD), other Government agencies, commercial firms, and other countries and international organizations.

Support is provided for Earth orbital, planetary and solar system exploration spacecraft missions, launch vehicles, research aircraft, sounding rockets and balloons. Included in Earth orbital support are the Space Shuttle, Spacelabs, and scientific and applications missions. The various types of support provided include: (a) tracking to determine the position and trajectory of vehicles in space; (b) acquisition of science and space applications data from on-board experiments and sensors; (c) acquisition of engineering data on the performance of spacecraft and launch vehicle systems; (d) reception of television transmissions from space vehicles; (e) transmission of commands from ground facilities to the spacecraft; (f) voice communications with astronauts; (g) transfer of information between the various ground facilities and control centers; and (h) processing of data acquired from the launch vehicles and spacecraft. Such support is essential for achieving the scientific objectives of all flight missions and for executing the critical decisions which must be made to assure the success of these missions.

Tracking and acquisition of data for the space projects is presently accomplished through the use of a worldwide network of NASA ground stations, and by two tracking and data relay satellites in geosynchronous orbit working with a highly specialized ground station. Ground facilities are interconnected by terrestrial and satellite communications circuits linking the spacecraft and their control centers for execution of the missions.

NASA has three basic support capabilities to meet the needs of all classes of NASA flight missions. These are the Spaceflight Tracking and Data Network (STDN), which currently supports Earth orbital missions; the Deep Space Network (DSN), which primarily supports planetary and interplanetary flight missions; and the Space Network, including the Tracking and Data Relay Satellite System (TDRSS), which will provide most low Earth orbital mission support when it becomes fully operational.

The STDN, managed by the Goddard Space Flight Center, will provide Earth orbital support until the TDRSS becomes operational. At that time the STDN phasedown will continue with the closure of several additional ground stations. The DSN, under the management of the Jet Propulsion Laboratory (JPL), provides support to geosynchronous, highly elliptical, and planetary and solar system exploration missions, as well as support to those spacecraft, now in low-Earth orbit, which are not compatible with TDRSS.

Highly specialized computation facilities provide real-time information for mission control and accommodate processing into meaningful form the large amounts of scientific, applications, and engineering data which are collected from flight projects. In addition, instrumentation facilities provide support for sounding rocket and balloon launchings and flight testing of aeronautical research aircraft.

The Space Flight, Control and Data Communications request includes the Space Network, STDN, DSN, and Communications and Data Systems elements of the program, and provides funding for: (a) TDRSS operations, spacecraft production, and launch support; (b) operations and maintenance of the tracking, data acquisition, mission control, data processing, and communications facilities; (c) the engineering services and procurement of equipment to sustain and modify the various systems to support continuing, new, and changing flight project support requirements; and (d) the spectrum management, frequency allocation, and flight data standards support functions for NASA.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The current estimate for FY 1989 of $945.3 million which is $90 million below the budget estimate and is consistent with Congressional action on the FY 1989 budget. The magnitude of this reduction required significant changes to program plans. Major schedule changes were required in the TDRSS replacement spacecraft and Second TDRSS Ground Terminal programs; additionally, many other program elements were subjected to reduced support capabilities, rephased implementation plans, and deferrals. These programmatic disruptions increase the risk that our support capabilities will not be fully ready to provide services to the flight programs needing support during the mid to late 1990's.

BASIS OF FY 1990 FUNDING REQUIREMENTS

SPACE NETWORK

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Tracking and data relay satellite system (TDRSS)	318,900	313,800	295,800	320,800
Space network operations	40,400	46,700	34,800	39,600
Systems engineering and support	26,700	25,600	31,600	32,400
TDRS Replacement spacecraft	35,800	78,800	58,600	44,400
Second TDRSS ground terminal	7,600	70,000	59,100	123,600
WSGT system replacement	--	--	--	15,500
Advanced TDRSS	4,000	4,000	4,000	6,000
Total	433,400	538,900	483,900	582,300

OBJECTIVES AND STATUS

The Space Network consists of the Tracking and Data Relay Satellite System (TDRSS) and a number of NASA ground elements to provide the necessary services to low Earth orbital spacecraft including the Shuttle. The TDRSS, when fully operational, will consist of a three satellite constellation, including an on-orbit spare, in geostationary orbit and ground facilities located at White Sands, New Mexico. From the White Sands location, satellite and ground communication links interconnect the NASA elements of the network and remotely located user facilities.

The FY 1990 request includes funding for: repayment of the loans extended by the Federal Financing Bank for TDRSS development; maintenance and operation of the White Sands complex and other NASA elements of the network; support activities such as systems engineering, documentation and mission planning; equipment modification and replacement; competitive design studies for the next generation TDRSS; the development of an additional spacecraft to replace the TDRS lost in the Challenger accident; and the modernization of the current ground terminal and beginning implementation of a second ground terminal at White Sands.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Tracking and data relay satellite system......................	318,900	313,800	295,800	320,800

OBJECTIVES AND STATUS

The Tracking and Data Relay Satellite System's (TDRSS) objective is to provide communications services between user spacecraft and ground facilities. The relay satellites provide space-to-space communications to and from user satellites and relay these communications to the White Sands ground facilities which are interconnected with the other elements of the network. From their position in geostationary orbit, the TDRS's can provide nearly a six-fold increase in the orbital coverage provided by ground tracking stations and can accommodate extremely high user data rates ranging up to 300 megabits per second.

The TDRS-1 was launched in April 1983, and since that time it has supported Shuttle missions, including Spacelabs, and free flyer satellite missions such as the Solar Maximum Mission (SMM), Earth Radiation Budget Satellite (ERBS), Landsat, and Solar Mesopheric Explorer (SME). The TDRS-2 was destroyed during the Challenger accident in January 1986. TDRS-3 was successfully launched in September, 1988, with the return of the Shuttle to flight status. The spacecraft has completed its initial checkout in an excellent manner and supported the STS-27 mission launched in December 1988. The next TDRS is scheduled for launch in the first quarter of 1989. Once this spacecraft is successfully deployed, the system will achieve full operational status and the TDRS-1 will become the on-orbit spare due to its degraded communications services capability.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $18 million from the FY 1989 budget estimate results from a deferral of the buildup of the sixth spacecraft, and reduced equipment replacement funding for the White Sands Ground Terminal.

BASIS OF FY 1990 ESTIMATE

The primary activity during FY 1990 will be the preparation of the fifth spacecraft for its launch. Low level assembly and test activities will be conducted on the sixth spacecraft as crew availability permits.

Under the terms of the TDRSS service contract, loans were extended by the Federal Financing Bank (FFB) to Space Communications Company (SCC), the owner-operator of the TDRSS, for program development. Under the terms of the loan agreement and assignment, NASA repays these loans directly to the FFB. In addition, NASA will make payments to SCC for service, the operation and maintenance of the White Sands complex, and for satellite construction and launch support provided during the year.

Of the amount requested in FY 1990, $227 million is for the FFB loan repayments. The remainder of the request is for continuing spacecraft activities, service payments, and operation and maintenance of the White Sands Ground Terminal.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Space network operations.................	40,400	46,700	34,800	39,600

OBJECTIVES AND STATUS

The objective of Space Network Operations is to provide for the operation and maintenance of the associated NASA ground systems and facilities which, when combined with TDRSS, provide a full array of reliable services to user spacecraft in low Earth orbit. These services are designed to function as part of an integrated operations system and perform specific functions for the Space Network.

The NASA Ground Terminal (NGT) monitors TDRSS performance, provides fault isolation monitoring for the network, and serves as the communications interface between White Sands and all other user facilities. The Network Control Center (NCC) manages and schedules TDRSS services for all user spacecraft, and the Flight Dynamics Facility (FDF) provides orbit determination, trajectory analysis, and position location for selected flight missions supported by the space and ground networks. The overall system has provided services to a variety of missions, and effort is continuing to achieve an operational configuration that will be capable of supporting the expanded workload in the early 1990's as the Shuttle flight rate increases.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $11.9 million from the FY 1989 budget estimate results primarily from reduced contractor support and lower than anticipated labor rates for this period.

BASIS OF FY 1990 ESTIMATE

The funding request provides for services to operate network facilities 24 hours a day, seven days per week, and for related hardware and software maintenance. Funding is also provided for a variety of support activities such as operational analysis, mission planning, simulations, user compatibility testing, and documentation.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Systems engineering and support..........	26,700	25,600	31,600	32,400

OBJECTIVES AND STATUS

The objective of Systems Engineering and Support is to provide the engineering services and hardware required to sustain and modify the NASA elements of the Space Network. Engineering services are supplied primarily through support service contracts. Preparations continue to assure ground system readiness for support of Shuttle flights, including the upcoming TDRS launch, and for full network operation once the TDRSS is fully operational. There is ongoing activity to sustain system reliability for current users and preparations are underway to meet the support requirements of upcoming missions such as the Hubble Space Telescope.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The increase of $6.0 million to the FY 1989 budget estimate is to provide continued advanced planning to support the development of Space Station operational concepts, interface definition for data handling and distribution, and support requirements definition. In addition, hardware and software modifications must be initiated in the Network Control Center (NCC) to provide the requisite interface to operate with the Second TDRSS Ground Terminal at White Sands.

BASIS OF FY 1990 ESTIMATE

Funds are requested to provide systems engineering, hardware and software maintenance, sustaining engineering support, test equipment, and vendor maintenance for specialized equipment and subsystems within the Space Network. Funds are also requested for continued software development and ongoing hardware implementation, replacement, and modification for the NCC.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
TDRS replacement spacecraft..............	35,800	78,800	58,600	44,400

OBJECTIVES AND STATUS

A contract has been awarded to TRW, the subcontractor for the TDRSS space segment, to provide a replacement spacecraft for TDRS-2, lost with the Challenger. The replacement spacecraft will assure TDRSS service continuity until the Advanced TDRS can be developed and deployed. The design objective is to provide a satellite functionally identical to the current satellites and fully compatible with the existing system. Modifications have been made to the original spacecraft design due to parts failure and obsolescence.

During the fourth quarter of FY 1989, the critical design review will be held, and the program emphasis will shift from design to fabrication. In FY 1990, spacecraft fabrication will be initiated with deliveries of structural components, reaction control system elements, and electronic components for both the spacecraft and its communications payload. Buildup of subsystem modules and assemblies will continue through FY 1990.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $20.2 million from the FY 1989 budget estimate reflects congressional action on the NASA FY 1989 budget request. This reduction was accomplished by terminating most of the long-lead parts procurement for an additional spacecraft and by delaying the launch readiness date of the replacement spacecraft from December 1991 to December 1992.

BASIS OF FY 1990 ESTIMATE

The requested funding will provide for continuation of the construction phase of the program. This phase will include completing all design activities and continued fabrication of the spacecraft bus and payload hardware. The launch readiness date of the replacement spacecraft is now under review and based on the current budget will not occur before mid-1993.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Second TDRSS ground terminal (STGT)......	7,600	70,000	59,100	**123,600**

OBJECTIVES AND STATUS

The objective of this program is to insure continuity of service and to minimize the potential loss of critical space assets, including science data. The existing terminal at White Sands, New Mexico, is a single point of failure for the entire Space Network, and a catastrophic failure of this terminal could result in a nearly complete loss of NASA communications and data gathering capabilities for Earth orbiting missions. In addition, the present terminal has experienced equipment failures causing temporary service outages which could have been avoided with a backup terminal.

Due to the aging of equipment, replacement of major subsystems and components in the existing terminal will eventually be required. This will necessitate an alternate means of conducting network operations while the replacement activity is underway. The addition of a second ground terminal will provide the necessary alternative means for continuing operational support while the existing terminal is down during modernization.

Because the design of the current terminal is limited to full operation of two TDRS spacecraft, a second terminal will also provide the additional flexibility to operate more spacecraft if, as anticipated, mission requirements exceed current capabilities in the mid 1990's. The General Electric Company was selected in October 1988 for final negotiations leading to award of a contract for the implementation of the STGT.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $10.9 million from the FY 1989 budget estimate reflects Congressional action and results in an anticipated slip in the planned program completion to June, 1993, approximately six months.

BASIS OF FY 1990 ESTIMATE

The FY 1990 funding level is required to initiate several large procurements of off-the-shelf equipment systems required early in the development of STGT for use in software development and proof of system designs. Extensive testing at the contractor facility will also be required during 1990 for compatibility with operational concepts. The purchase of equipment will ensure a more cost effective and efficient procurement process by purchasing in quantity. Equipment systems to be purchased include antennas, radio frequency receivers and transmitters, power supplies, and computer/ADPE hardware. In addition, fabrication of additional custom designed hardware systems will be initiated during FY 1990. During late FY 1990, the extensive system engineering and design efforts will culminate in a final design concept for STGT. The above activities need to occur during FY 1990 in order to meet a required completion date of late 1993.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Estimate
		(Thousands of Dollars)		
White Sands Ground Terminal (WSGT) System Replacement	--	--	--	15,500

OBJECTIVES AND STATUS

The objective of the WSGT System Replacement is to provide long term reliability and life cycle cost savings for the White Sands ground terminal operation. The Second TDRSS Ground Terminal (STGT) is planned to be operational by the end of 1993, and its advent will provide the opportunity to undertake the modernization of the WSGT systems which have been in operation since 1979. The replacement systems will be identical to those in the STGT.

The replacement of the WSGT systems provides a two-fold benefit to long-term Space Network operations. First, the aging equipment and the error-prone, difficult-to-maintain architecture of the original ground terminal will be replaced with updated technology and the inherently more reliable architecture of the STGT, simplifying operations and maintenance. Second, the existence of two identical, more reliable ground terminals allows greatly reduced operational staffing through the use of common hardware and software maintenance facilities, logistics, and engineering support.

BASIS OF FY 1990 ESTIMATE

The requested funding will provide for procurement of additional STGT systems to modernize the current WSGT. This procurement will be initiated upon completion of the STGT Critical Design Review. The procurement of these systems will allow additional units to be built as part of the STGT production, thereby lowering unit hardware costs and avoiding additional nonrecurring engineering costs.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Advanced Tracking and Data Relay......... Satellites (ATDRS)....................	4,000	4,000	4,000	6,000

OBJECTIVES AND STATUS

The objective of the program is to design, develop and competitively procure technologically advanced satellites to sustain Space Network operations. By the mid-1990's, the stock of ground spare spacecraft for the Tracking and Data Relay Satellite System (TDRSS) is expected to be exhausted. The ATDRS will provide the capability to extend network service into the 21st century and to accommodate the future mission requirements projected for this era. Initial studies are in progress and will be completed during FY 1989.

BASIS OF FY 1990 ESTIMATE

Requested funding is required to initiate the design definition (Phase B) studies. Current plans are to select several contractors in the last quarter of FY 1990 to perform ATDRS definition studies.

BASIS OF FY 1990 FUNDING REQUIREMENTS

GROUND NETWORKS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network systems implementation	3,200	6,200	4,500	4,400
Spaceflight tracking and data network operations	68,000	65,700	64,600	66,600
Deep space network systems implementation	46,200	50,100	39,700	63,400
Deep space network operations	88,900	99,000	95,700	103,500
Aeronautics, balloons, and sounding rocket support systems implementation	8,200	9,300	6,800	11,800
Aeronautics, balloons, and sounding rocket support operations	16,500	17,800	16,800	19,900
Total	231,000	248,100	228,100	269,600

OBJECTIVES AND STATUS

The Ground Networks provide support to three broad categories of missions: Earth orbital spaceflight; planetary and solar system exploration; and aeronautics, balloons and sounding rockets. Earth orbital support is provided primarily by the Spaceflight Tracking and Data Network (STDN), a network of eight geographically dispersed ground stations. The Deep Space Network, with ground stations located at three sites approximately 120 degrees apart in longitude, provides support to the planetary and solar system exploration missions as well as Earth orbital missions not compatible with TDRSS. Aeronautical, balloon and sounding rocket research is supported by specially instrumented ranges as well as mobile systems.

Funding for the Ground Networks provides for operation and maintenance of the worldwide tracking facilities, engineering support, and the procurement of hardware and software to sustain and modify network capabilities as required to support new missions. The workload in FY 1990 will include support to the Space Shuttle and the Ulysses spacecraft launch. Magellan will begin radar mapping of Venus and Galileo will swing by Venus for its first gravity assist during FY 1990. Preparations will be underway for the FY 1992 Mars Observer planetary encounter missions and the GGS and COSTR missions. Voyager-2 encounter with the planet Neptune, in FY 1989, and ongoing missions such as Dynamic Explorer (DE), International Ultraviolet Explorer (IUE), and Solar Maximum Mission (SMM) will continue to receive Ground Networks and/or Space Network support. Aircraft test programs will also be supported.

The STDN stations at Ascension Island, Guam, Chile, and Hawaii, and Yarragadee, Australia are planned to be phased out following the achievement of TDRSS operational status. Station operations at these sites will cease on September 30, 1989. The operation of the Merritt Island and Bermuda stations will continue; these stations will be primarily used for STS prelaunch, launch, range safety, and landing support. Some limited non-routine orbital support will also be provided.

A new advanced development antenna will be completed at Goldstone in 1990. This antenna will permit research on advanced beam waveguide techniques and enable the DSN to migrate to higher, more efficient communications frequencies such as Ka band. A new, more accurate, technique for measuring the electron content of the ionosphere will be employed during FY 1990. This measurement is critical to all ground-based navigation of distant spacecraft since it is required to compensate for the bending of radio waves as they pass through the ionosphere. This technique will use Global Positioning System satellites in conjuction with a special receiver and processor at each of the DSN complexes.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Spaceflight tracking and data network systems implementation.................	3,200	6,200	4,500	4,400

OBJECTIVES AND STATUS

The Spaceflight Tracking and Data Network (STDN) systems implementation program encompasses the procurement of hardware and attendant engineering services to sustain, modify, and replace existing network capabilities to ensure reliable tracking, command and data acquisition support to NASA's spaceflight missions.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $1.7 million reflects program adjustments that are being made to accommodate a portion of the general reduction specified by Congress.

BASIS OF FY 1990 ESTIMATE

The FY 1990 request includes funds to upgrade equipment and subsystems at the Merritt Island, Florida, and Bermuda STDN'tracking stations, which will continue in service after the TDRSS is operational. The request also includes funding for the replacement of obsolete, difficult-to-maintain equipment at these tracking stations and at other network facilities. In addition, the funds requested will provide for the procurement of major subsystems spare components, the replacement of older test equipment, and minor equipment modifications to accommodate changes in support requirements.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network operations....................	68,000	65,700	64,600	66,600

OBJECTIVES AND STATUS

The primary function of the Spaceflight Tracking and Data Network (STDN) system is to support NASA's Earth orbiting spaceflight missions, including the Space Shuttle. This network also provides launch support to NASA planetary missions, and on a reimbursable basis, spaceflight missions of other United States government agencies (NOAA and DOD), private industry, and other nations.

The STDN presently consists of eight geographically dispersed ground stations located at: Merritt Island, Florida; Kauai, Hawaii; Guam; Ascension Island; Dakar, Senegal; Bermuda; Santiago, Chile; and Yarragadee, Australia. Each of these stations, with the exception of Yarragadee, have the capability to electronically track spacecraft, send commands for spacecraft and experiment control purposes, and receive engineering and scientific data from the spacecraft. In the case of manned flights, they also maintain voice communications for crew operations and safety and other project-related purposes. The Yarragadee, Australia, station provides only air-to-ground voice communication with the Space Shuttle astronauts.

At the beginning of FY 1990, the STDN will undergo a highly significant change from its current configuration when the Space Network achieves operational status. At that time five STDN stations will cease operations and either close or be transferred to other organizations. The stations scheduled to close on September 30, 1989 are Ascension Island; Guam; Hawaii; Santiago, Chile; and Yarragadee, Australia. The station at Dakar, Senegal will continue operating until the fifth TDRSS spacecraft is in orbit. The remaining stations at Merritt Island, Florida, and Bermuda will continue indefinitely for providing Shuttle prelaunch, launch, and landing support as well as limited orbital support.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $1.1 million reflects program adjustments that are being made to accommodate a portion of the general reduction specified by Congress.

BASIS OF FY 1990 ESTIMATE

The FY 1990 funding request provides for a full year of operation of the STDN stations at Merritt Island, Florida; Bermuda; and Dakar, Senegal. It also provides funding for closeout activities for the five stations that are scheduled to cease operations on September 30, 1989. The request includes funding for logistics support, network planning, scheduling, control center operations, engineering, documentation, and software programming support. Logistics support funded under this program is provided to a variety of users such as the Tracking and Data Relay Satellite System; the Deep Space Network; the NASA Communications Network; the Aeronautics Balloons and Sounding Rocket Support program; and spacecraft control centers.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Deep space network (DSN) systems implementation........................	46,200	50,100	39,700	63,400

OBJECTIVES AND STATUS

The primary role of the Deep Space Network (DSN) is to provide the communication links between planetary and interplanetary spacecraft and the Earth. The DSN receives science and engineering data from the spacecraft and transmits navigation, command and control signals to a variety of spacecraft hundreds to billions of kilometers from Earth.

The systems and facilities required to support spacecraft at the limits of the solar system are highly specialized and include the use of large aperture antennas electronically configured in arrays to receive the extremely weak radio signals. The antennas use ultrasensitive receivers and powerful transmitters. Extremely stable time standards are required for precise navigation of distant spacecraft. Advanced data handling systems are required at both the Network Operations Control Center located at the Jet Propulsion Laboratory (JPL) and the DSN complexes. Systems implementation are required to support the Magellan launch in April, 1989; the Neptune encounter of Voyager-2 in August, 1989; the Galileo launch in October, 1989; and the Dynamics Experiment on Phobos which begins in April, 1989. Preparations to support the Mars Observer, Topex, GGS, COSTR, and CRAF/Cassini missions are also underway.

The five major objectives of the DSN are as follows: (1) to provide communications links to scientific spacecraft at greater distances and to increase the capability to receive images at these distances; (2) to increase the frequency range and data rate capability of the ground network to accommodate new deep space mission requirements; (3) to provide mission support for Earth orbiting spacecraft which are non-TDRSS compatible; (4) to provide improved navigation capabilities for precise spacecraft targeting and probe delivery; and (5) to provide emergency support to TDRSS compatible spacecraft.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $10.4 million reflects program adjustments that are being made to accommodate a portion of the general reduction specified by Congress. This sizeable reduction resulted in the stretchout of several major program implementations including those supporting Topex, microwave observing project, and development of an improved planetary radar capability.

BASIS OF FY 1990 BUDGET ESTIMATE

Funding in the FY 1990 request provides for sustaining activities required to keep the DSN functioning in a highly reliable manner. In addition, FY 1990 funding provides for the development of new DSN capabilities to support the following missions and projects: Magellan, Mars Observer, Topex, Galileo, GGS, COSTR, and CRAF/Cassini. These capabilities include changes to the data systems at the tracking stations and the control center, the stations' radio frequency systems, and the stations' receiving systems. The transmitting power levels of the Goldstone and Arecibo radars are being increased to improve the resolution and range for the Solar Radar program studies on asteroids and landing sites.

Engineering studies will begin in FY 1990 for the first of three new 34-meter beam waveguide antenna. These three antennas will replace the oldest antennas in the network, which are now at the end of their useful lifespan. The design for the new antennas will be based upon the results obtained from the Advanced Development Antenna at Goldstone.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Deep space network operations............	88,900	99,000	95,700	103,500

OBJECTIVES AND STATUS

The three Deep Space Network (DSN) complex locations--Goldstone, California; Canberra, Australia; and Madrid, Spain--are approximately 120 degrees apart in longitude to permit continuous viewing of planetary spacecraft. Each complex has four antennas -- one 70-meter, two 34-meter, and one 26-meter. The 26-meter antennas are used to support Earth orbiting spacecraft, such as the Space Shuttle. The complexes will be staffed for around-the-clock operations to support the critical 1989 deep space workload. Major new missions to be supported during this year are Magellan, the Voyager-2 encounter with Neptune, and Phobos. Final preparations will be concluded for the Galileo launch, scheduled for October 1989.

A centralized network control center is located at the Jet Propulsion Laboratory (JPL) in Pasadena, California. Other DSN facilities include a spacecraft compatibility test area at JPL and a launch operations and compatibility facility at the STDN Merritt Island tracking station.

The DSN facilities are also used for ground-based measurements in support of experiments in solar system radar and in the field of radio astronomy. The ultrasensitive network antennas are being used in an attempt to learn more about pulsar high energy sources, quasars, and other interstellar and intergalactic phenomena.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $3.3 million reflects rephasing of activities to accommodate a portion of the general reduction specified by Congress.

BASIS FOR FY 1990 ESTIMATES

The DSN operations funding provides for the maintenance and operation of network facilities and the support and engineering effort required for continuing operation of the network. The expected DSN workload in FY 1990 consists of support for Magellan, Galileo --- including a Venus gravity assist, Phobos, and Ulysses, as well as ongoing support to a variety of missions. These missions include Pioneers-10 and -11; Pioneer-Venus; Voyagers 1 and 2; Active Magnetospheric Particle Tracer Explorer (AMPTE); International Cometary Explorer (ICE); Nimbus-7; Dynamics Explorer (DE); and Solar Maximum Mission (SMM), which is expected to reenter the Earth's atmosphere in 1990. The DSN will also provide emergency and backup support to the Space Shuttle, TDRSS, Hubble Space Telescope, and Cosmic Background Explorer (COBE).

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Aeronautics, balloons and sounding rocket support systems implementation..	8,200	9,300	6,800	11,800

OBJECTIVES AND STATUS

The facilities of the Aeronautics, Balloon and Sounding Rocket (AB&SR) program encompass the ground support capabilities required to capture the scientific and engineering data from aircraft, balloons, sounding rockets and some Earth orbiting vehicles engaged in scientific research. The primary fixed facilities are located at the Wallops Flight Facility (WFF), the Moffett Field Flight Complex (MFFC) and the Dryden Flight Research Facility (DFRF).

The Wallops Flight Facility, under the management of Goddard Space Flight Center (GSFC), operates an extensive range at Wallops Island, Virginia, which supports aeronautics research as well as sounding rocket and small meteorological balloon launches, In 1986, a capability was established at WFF to provide tracking and data acquisition support to certain Earth orbiting satellites to supplement the capabilities of the Spaceflight Tracking and Data Network (STDN). WFF also manages the operation of off-site ranges located at the White Sands Missile Range, New Mexico; Poker Flats Research Range, Alaska; and the National Scientific Balloon Facility, at Palestine, Texas. Mobile campaigns for balloon and sounding rocket launches are conducted at various sites throughout the world.

The ranges at Moffett Field, Crows Landing and the Dryden Flight Research Facility (DFRF) are under the management of Ames Research Center (ARC) and are configured to support aeronautics research. The DFRF has the additional capability to support Shuttle landings.

The AB&SR system implementation program is directed primarily at the systematic replacement of obsolete systems and the upgrade of these facilities to assure reliable support to NASA's research programs.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $2.5 million reflects program adjustments that are being made to accommodate a portion of the general reduction specified by Congress. The reduction was accomplished by deferring system, supply and support services procurements.

BASIS OF FY 1990 ESTIMATE

Support to the aeronautical research efforts and scientific experiments using sounding rockets and balloons requires fixed and mobile instrumentation systems which include radar, telemetry, optical, communications, command, data handling and processing systems. To maintain these facilities, replacement parts must be acquired, test and calibration equipment routinely replaced, and equipment refurbished or modified to assure reliable support. The FY 1990 funding estimate also includes system, supply and support services procurements deferred to FY 1990 that could not be accommodated within the FY 1989 reduced funding levels.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Aeronautics, balloons, and sounding rocket (AB&SR) support operations......	16,500	17,800	16,800	19,900

OBJECTIVES AND STATUS

The operations element of the AB&SR program includes the operations and maintenance of ground-based instrumentation systems, both fixed and mobile, under the management of the Ames Research Center (ARC) and the Goddard Space Flight Center (GSFC). These facilities support NASA aeronautics, sub-orbital, and a limited number of Earth orbit research programs. Funding provides for services and consumable supplies required to operate and maintain the radar, telemetry, data acquisition, data processing, data display, communications and special purpose optical equipment essential to the conduct of these research programs.

The aeronautical test ranges at the Dryden Flight Research Facility (DFRF) and the Moffett Field Flight Complex (MFFC), under the auspices of the Ames Research Center, maintain an active schedule of aeronautics research support. During FY 1988, more than 1625 missions were conducted at DFRF and MFFC. In FY 1989, approximately 1700 aeronautical missions will be supported at these locations. Programs supported by the ranges encompassed a wide variety of activities including revolutionary aircraft configurations, advanced technologies, high performance aircraft, highly integrated control systems and powered lift technologies.

The GSFC activities support aeronautics programs as well as sounding rocket, balloon and Earth orbiting satellite programs at the Wallops Flight Facility (WFF). During 1988, approximately 220 aeronautics missions were supported at the WFF covering such programs as heavy payload mid-air retrieval systems development, XV-15 Aircraft Noise Program, runway friction testing, microwave landing system operations testing, storm hazards research, and the general aviation light aircraft thruster research program. In 1989, approximately 220 aeronautical missions will be supported by WFF.

The sounding rocket program at the WFF conducted approximately 33 launches in FY 1988 of rockets with major scientific payloads. In FY 1990, approximately 40 such launches will be supported. In addition, WFF launched a number of the smaller meteorological and special purpose rockets supporting a variety of research programs. In support of the NASA scientific balloon program, WFF launched 46 large balloons in FY 1988 with major scientific payloads. In FY 1989, approximately 55 large balloon launches will be supported. Earth orbiting satellites supported included International Ultraviolet Explorer, Interplanetary Monitoring Platform-8, and Nimbus-7, Dynamics Explorer-1, Meteosat, and Landsat.

CHANGES FROM FY 1989 BUDGET ESTIMATES

The decrease of $1.0 million reflects program adjustments that are being made to accommodate a portion of the general reduction specified by Congress.

BASIS FOR FY 1990 ESTIMATE

The funding estimate for FY 1990 is based on a level of activity about 10 percent higher than the FY 1989 level of effort but also includes maintenance and support services deferred to FY 1990 that could not be accommodated within the FY 1989 reduced funding level. The specific adjustments included deferred maintenance on the FPS-16 and FPQ-6 radars, control center engineering support, and logistics support. The funding for AB&SR program operations includes support services contractor operations and maintenance personnel, logistical support, and technical services for the ground-based fixed and mobile instrumentation systems supporting the ongoing sounding rocket, balloon, Earth orbiting satellite and aeronautical research programs.

BASIS OF FY 1990 FUNDING REOUIREMENT

COMMUNICATIONS AND DATA SYSTEMS

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Communications systems implementation....	7,000	12,100	10,400	12,500
Communications operations................	109,400	116,300	108,400	115,500
Mission facilities......................	9,900	8,800	8,800	7,800
Mission operations......................	25,400	32,000	31,200	38,700
Data processing systems implementation...	22,200	25,800	25,500	20,900
Data processing operations..............	41,100	53.300	49.000	54.800
Total................................	215.000	248.300	233.300	250.200

OBJECTIVES AND STATUS

Funds requested for the Communications and Data Systems program provide for the implementation and operation of facilities and systems which are required for data transmission, mission control and data processing support.

Communication circuits and services provide for the transmission of data between and among the remote tracking and data acquisition facilities, the TDRSS Ground Terminal, launch areas, and the mission control centers. Real-time information is crucial to determine the condition of the spacecraft and payloads for the generation of spacecraft and payload control commands. Data received from the various spacecraft must be processed into a usable form for spacecraft monitoring in the control centers and before the transfer of data to the experimenters. Missions supported include Shuttle, Spacelab, NASA scientific and application projects, and international cooperative efforts.

Major activities underway include: implementing necessary changes and completion of testing of the Hubble Space Telescope mission control and data capture system, and mission control and data processing capabilities required to support upcoming missions such as Gamma Ray Observatory (GRO), Spacelabs, Upper Atmosphere Research Satellite (UARS), Global Geospace Science (GGS), Collaborative Solar Terrestrial Research (COSTR), Cosmic Background Explorer (COBE), and Advanced X-ray Astrophysics Facility (AXAF). In addition, studies are continuing to evaluate Space Station support requirements.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Communications systems implementation.....	7,000	12,100	10,400	12,500

OBJECTIVES AND STATUS

The objective of the Communications Systems Implementation program is to provide the necessary capability in NASA's Global Communications Network (NASCOM) to meet new program support requirements, to increase the efficiency of the network, and to keep NASCOM at a high level of reliability for the transmission of data. NASCOM interconnects the tracking and data acquisition facilities which support all flight projects and also links such facilities as launch areas, test sites, and mission control centers.

The major effort being initiated in NASCOM is the planning, engineering, and equipment acquisition required to tie together the existing TDRSS ground terminal at White Sands, New Mexico, with the Second TDRSS Ground Terminal (STGT). This requires an integrated communications capability for the control and transfer of data between the two facilities. The secondary effort under way is the equipment acquisition to upgrade the Deep Space Network's ground communications data handling capability at Madrid, Spain; Tidbinbilla, Australia; and the Jet Propulsion Laboratory.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $1.7 million reflects program adjustments that are being made to accommodate a portion of the general reduction specified by Congress. It is necessary to slip the implementation of the facility communications for the STGT discussed above for six months as part of this accommodation, consistent with the reduction in the STGT.

BASIS OF FY 1990 ESTIMATE

The FY 1990 funding requirements will provide the sustaining equipment and modifications to support the NASCOM network and provide for the continued engineering and equipment acquisition to support the STGT at White Sands. New periperals will be purchased to replace the outmoded models presently in use for the message switching system (MSS). Funding will also provide for the increased ground communications data handling capability required in the Deep Space Network to support the combined data rates of the Magellan, Galileo, and Ulysses satellites.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Communications operations...........	109,400	116,300	108,400	115,500

OBJECTIVES AND STATUS

NASA's global Communications Network (NASCOM) interconnects, by means of leased voice, data, and wideband circuits, the tracking and data acquisition facilities which support all flight projects. Also, NASCOM links such facilities as launch areas, test sites, and mission control centers. Goddard Space Flight Center (GSFC) operates the NASCOM and serves as its major switching control point. In the interest of economy, reliability, and full utilization of trunk circuitry, subswitching centers have been established at JPL and Madrid. The NASA flight projects require the transfer of data between the mission control centers and the sites because of the need for real time control of spacecraft and on-board experiments.

NASA's Program Support Communications Network (PSCN) interconnects the NASA Centers, Headquarters, and major contractor locations through leased voice, data and wide-band circuits for the transfer of programmatic and scientific information. Marshall Space Flight Center (MSFC) operates the PSCN and serves as its major switching control point.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $7.9 million reflects program adjustments that are being made to accommodate a portion of the general reduction specified by Congress. The adjustments include delaying implementation of new requirements on the PSCN and savings associated with the revised Shuttle manifest.

BASIS OF FY 1990 ESTIMATE

The FY 1990 funding requirements for the NASCOM Communications Operations program will provide the circuits and service required to operate and maintain the NASA Global Communications Network. International communications satellites and cables will continue to provide digital wideband services to all the overseas tracking stations. Domestic satellite systems and terrestrial networks will continue to service the continental United States stations. With the reactivation of the Shuttle communications network and the trend toward fiber optic systems, there will be a dramatic increase in the use of digital technology in NASCOM with a corresponding decrease in the use of analog technology. Funding is also required to simultaneously support the Shuttle and the deep space projects with wideband data links to the Deep Space Network stations in Spain and Australia.

Funds are included for Program Support Communications Network (PSCN) which provide for the circuits and facilities for programmatic operations such as data transmission and computer-to-computer data sharing for NASA Centers and Headquarters. In FY 1990, funds are required to operate and maintain the PSCN hardware and wideband satellite and terrestrial circuits at all NASA locations and selected contractor sites. The network will support all NASA programs and projects such as the Shuttle, Hubble Space Telescope, and Space Station Freedom.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Mission facilities......................	9,900	8,800	8,800	7,800

OBJECTIVES AND STATUS

The Mission Facilities Implementation program provides the capabilities needed for the command and control of NASA's unmanned scientific and applications satellite programs. Command and control of the spacecraft and on-board experiments are carried out via the Payload Operations Control Centers (POCC's) and related mission support systems.

The POCC's are responsible for the receipt, processing, and display of spacecraft engineering data and the transmission of commands. Four POCC's currently monitor and control numerous spacecraft. In addition, a new dedicated control center is nearing completion for control of the Hubble Space Telescope scheduled for launch in the first quarter of FY 1990. Related mission support systems include a Johnson Space Center/Goddard Space Flight Center Shuttle POCC Interface Facility (SPIF) and a Mission Planning/Command Management System to schedule spacecraft support and generate command sequences for transmission to the spacecraft by the POCC's.

BASIS OF 1990 ESTIMATE

The FY 1990 funding requirements will provide for completion of Hubble Space Telescope prelaunch systems testing and for continuing software development. This software will make the operation of the spacecraft more efficient resulting in increased science return, and will provide modifications determined to be required during the final ground testing and early orbit phases of the mission.

Also in FY 1990, funds are included for modifications to the existing Multi-satellite Operations Control Center (MSOCC) for control of the Gamma Ray Observatory (GRO), Upper Atmosphere Research Satellite (UARS), Extreme Ultra-Violet Explorer (EWE), GGS, COSTR, and various Shuttle attached payloads. In addition to the new spacecraft support capabilities being provided, the outmoded MSOCC switches, which route data throughout the control center and to and from external sources, will be replaced in FY 1990.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Mission operations......................	25,400	32,000	31,200	38,700

OBJECTIVES AND STATUS

The Mission Operations program in FY 1990 will provide for the operation of the five Payload Operations Control Centers (POCC's) and the related software and support services necessary for the monitoring and control of eight in-orbit spacecraft and prelaunch preparations for five new spacecraft.

The POCC's, which are the control facilities for spacecraft/payload operations, have the capability for receiving, processing, and displaying spacecraft engineering and telemetry data and for sending commands to the spacecraft. Commands transmitted to the spacecraft include both emergency commands resulting from decisions made by the spacecraft analysts and preplanned command sequences generated in advance to carry out the mission objectives. Each POCC is operated 24 hours per day, 7 days per week in mission support. For Shuttle missions with attached payloads operated by GSFC, there is a specialized GSFC Shuttle Payload Interface Facility (SPIF) which processes and provides for the display of Shuttle-unique data that is necessary for payload control.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $.8 million reflects program adjustments that are being made to accommodate a portion of the general reduction specified by Congress. This reduction has resulted in a slowdown of software development in FY 1989 for UARS, EWE, GGS, and COSTR.

BASIS OF FY 1990 ESTIMATE

The FY 1990 budget request includes funds to operate the POCC's and supporting facilities for control of on-orbit missions and to develop control center software to support upcoming missions. In early FY 1990, the new Hubble Space Telescope (HST) will be launched, followed by an intense period of on-orbit checkout of this new observatory. FY 1990 funds will provide the first full year of around the clock, seven days per week, operation in the HST control center to support the preparations for launch, perform the operational checkout and calibration of the spacecraft, its scientific instruments, and for the operation of the observatory to obtain scientific data. Also in FY 1990, software development activities will continue for the GRO and UARS missions, and the software development activities will increase for the EWE, GGS, COSTR, and AXAF spacecraft to meet the planned launch dates.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
	(Thousands of Dollars)			
Data processing systems implementation...	22,200	25,800	25,500	20,900

OBJECTIVES AND STATUS

The Data Processing Systems Implementation program provides for the procurement of equipment and related services for the large data processing and computation systems at the Goddard Space Flight Center (GSFC). These systems support both the operational and payload requirements of flight missions. To meet operational requirements, these systems determine spacecraft attitude and orbit and generate on-board commands to the spacecraft subsystems. In support of spacecraft payloads, the systems process the data from science and applications experiments for subsequent transfer to the experimenters for analysis.

Major computation capabilities include the Flight Dynamics Facility which performs the real-time attitude, orbit computation and flight maneuver control functions and the Mission Operations and Data Systems Information Network (MODSIN). Also included is the improvement in the test bed facility to be used for prototyping, testing, and evaluating maturing technologies resulting from the Advanced Systems Program. Promising technologies for application to future support will be investigated in the areas of remote payload operation and control, expert systems, high speed data processing, high level languages, and very large scale integration (VLSI). In addition, there are four major systems for processing payload data: 1) the Telemetry On-Line Processing System (TELOPS) which routinely supports a number of Earth-orbiting spacecraft; 2) the Image Processing Facility (IPF) which can support satellite imaging requirements; 3) the Spacelab Data Processing Facility (SLDPF) which has provided support to the Spacelab missions and the Shuttle Imaging Radar-B experiment; and 4) the Hubble Space Telescope Data Capture Facility (HSTDCF) which will capture, process, and forward to the Science Institute Facility the packetized telemetry data from the Hubble Space Telescope spacecraft. Significant activities in this program continue at GSFC to keep the large systems viable and responsive to project support requirements. Implementation continues on new systems to process data from the Gamma Ray Observatory (GRO) and the Upper Atmosphere Research Satellite (UARS) missions.

Multiple contractors will be chosen for definition studies and preliminary design for the Customer Data and Operations Systems (CDOS) in FY 1989. These studies will be for new institutional communications and data systems capabilities required to support the Space Station Freedom Program and other payloads in the Space Station era.

CHANGES FROM FY 1989 BUDGET ESTIMATE

The decrease of $0.3 million reflects program adjustments that are being made to accommodate a portion of the general reduction specified by Congress.

BASIS OF FY 1990 ESTIMATE

The FY 1990 budget request will provide continued funding for improvements in the existing computation systems at GSFC which provide real-time support to NASA spacecraft. Funding is also included for continuation of development of the MODSIN Host system and initial development of a generic application software for combined operational mission planning and attitude support system. In addition, the request provides for the improvement and upgrade of the Flight Dynamics Facility (FDF) and for systems studies in autonomous navigation.

The FY 1990 budget request also includes funds to continue the upgrade of the existing TELOPS system in order to develop a generic time division multiplexed (TDM) system for processing data. The Upper Atmosphere Research Satellite (UARS), will be the first user. The handling of UARS data will serve as a demonstration for providing such support to other users and allow trade-off analyses between development costs and support risks for future missions. Funds are also requested for upgrading the data processing capabilities at GSFC to facilitate the exchange of data within the data processing complex and with other mission support facilities.

Requested funding provides for the procurement and maintenance of an adequate supply of unique spare parts to replace failure-prone and high-maintenance electronic modules, to provide test equipment, and to undertake minor modifications and hardware fabrication associated with new equipment installation and reconfiguration.

Funds are included in the request for continuing the evaluation of Space Station support requirements and the capabilities needed to meet those requirements. The systems definition study will be completed for the Customer Data and Operations Systems (CDOS) which will provide a preliminary design and specifications leading to a projected system readiness date of July 1995.

	1988 Actual	1989 Budget Estimate	1989 Current Estimate	1990 Budget Estimate
		(Thousands of Dollars)		
Data processing operations...............	41,100	53,300	49,000	54,800

OBJECTIVES AND STATUS

Information received in the form of tracking and telemetry data from the various spacecraft must be processed into a usable form before transfer to the experimenters. This transformation and computation process is performed as part of the data processing function and applies to a wide variety of programs, ranging from the small Explorer satellites to more complex imaging satellites.

In addition to the actual processing of data, upcoming projects require extensive prelaunch orbit analysis. Spacecraft position and attitude predictions analyses are also required to develop operational sequences and procedures. Benefits from these studies include optimization of systems resources such as, look angles for maximum science data return during the actual spacecraft operation. Similar efforts will focus on flight dynamics support for the COBE launch in FY 1989.

Telemetry data is the primary product of spacecraft, and it is through reduction and analysis of this data by the experimenters that the mission objectives are achieved. Data are processed to separate the information obtained from various scientific experiments aboard the spacecraft, to consolidate information for each experimenter, to determine spacecraft attitude, and to correlate these measurements with time and spacecraft position data. Four facilities, the Image Processing Facility (IPF), the Telemetry On-Line Processing System (TELOPS) facility, the Spacelab Data Processing Facility (SLDPF), and the Hubble Space Telescope Data Capture Facility (HSTDCF) have been established at the Goddard Space Flight Center to preprocess different types of raw experiment data. Sustained operations of these facilities is needed to support the ongoing spacecraft in-orbit.

The IPF, initially established to handle image data from the Landsat-1 satellite, has supported many missions over the ensuing years. The TELOPS handles satellite non-image data which is received in a digital form from the tracking stations via NASCOM. It is capable of electronically storing large volumes of telemetry data, thus eliminating most of the tape and tape handling operations. Facility management, maintenance and operations, and software development support for the image and non-image data processing facilities are also provided. The operation of the SLDPF is included along with software development and maintenance required for attitude determination, flight maneuvers, mission simulations, and the Mission Operations and Data Systems Information Network (MODSIN).

CHANGES FROM FY 1989 **BUDGET ESTIMATE**

The decrease of *$4.3* million reflects program adjustments that are being made to accommodate a portion of the general reduction specified by Congress. This budget reduction will impact operational support in FY 1989 by reducing staffing in the Telemetry On-line Processing System (TELOPS) Facility and scaling back Spacelab mission support in FY 1989 which results in the delayed delivery of data from missions requiring TELOPS or the Spacelab Data Processing Facility (SLDPF) support.

BASIS OF FY **1990 ESTIMATE**

The FY 1990 budget request provides for operation of the various computation and data processing facilities including the SLDPF which provides unique hardware and software support to Spacelab and Dedicated Discipline Laboratory (DDL) missions. Pre-mission, mission and post-mission support for FY 1990 launch of Astro-1/BBXRT, Starlab, Atlas-1, and SLS-1 missions is required. In addition, preparation for future missions such as TSS-1, Wamdii, SL-J, and Astro-2, will be continued. Support for ongoing spacecraft, such as, SMM, IUE, ICE, ERBS, DE, and COBE consists of software enhancements and maintenance on a continuing basis in order to perform flight control and maneuver operations and for the data processing activities. Funding is required to support the Space Station Platform Flight Dynamics analysis and CDOS software support environment (SSE) buildup.

Application software development, prototyping, and system testing are continuing for upcoming science and applications missions such as AXAF, GGS, COSTR, GRO, ASP, UARS, and EWE. Funding is also required for the Solar Heliospheric Observatory (SOHO) element of COSTR.